DIRT BANDS ON A GLACIER—MER DE GLACE

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Frontispiece

Ice Ages

The Story of the Earth's Revolutions

By

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PREFACE

In two earlier little works (*The A B C of Evolution* and *The Evolution of Civilization*), of the same very modest proportions as this, I have given an outline of the story of Evolution. It is clear from the large circulation of these simple manuals that they have met a very real want. A good proportion of the workers, for whom in particular I write, feel that science means a new and mighty mental power in the world. They are asking if its broad teaching about man and the universe cannot be made plain to them without the use of learned words which they have not time to study, and without masses of detail which only tire them.

These short and plain summaries of science endeavour to supply that want. Twenty years' lecturing on the subject has educated me in the work of translating the language of the laboratory into the speech of the fireside. There is no branch of culture (except metaphysics, which is not worth it, and mathematics, which is for mathematicians) that cannot be conveyed in plain speech. I have given the same lecture, on the Evolution of Life, one night in one of the leading universities of America and the next night to a ragged group of children in one of the slums of New York.

It is possible thus to teach, not merely science, but the most profound, most stimulating, and most recent truths of science. "Popular science" is a phrase that men of science do not like. Much that goes by that name is a loose statement of things that have been published in works that are already a little out of date. That is not the kind of science I give here. Each of these little manuals is based upon the whole literature of the subject, in various tongues, and upon the expert periodicals for each branch of the subject up to the date of publication. The difficulty is, even after leaving out what is unsuitable for these works, to compress so much matter without leaving it in a hard and not easily digested form. A good deal has to be omitted, or insufficiently explained. This, it seems, is notably the case in regard to my earlier references to Ice Ages. I describe them as having played a revolutionary part in the advance of life on the earth, and I am told that this is so helpful, so interesting, and so important that readers would like fully to understand them and their effects. So here I offer, in the same plain, untechnical manner, an outline of the really wonderful story of the earth's revolutions.

J. M.

March, 1922.

PREFACE TO AMERICAN EDITION

A WRITER of large imagination once suggested that a being travelling outward from the earth at a certain speed would pick up in succession the entire past history of our globe. Unfortunately, one would have to travel at a higher speed than light—more than 186,000 miles a second;—apart from the practical difficulties, Einstein has now proved that nothing *can* travel more speedily than light!

But science has found a more practicable way of piecing together the romance of the earth. Indeed, when one reflects, one sees that this patient reconstruction out of the crushed and half-obliterated tombs of the past is one of the most marvellous triumphs of the human mind. The part which Ice Ages have played in this wonderful past increases in interest and scientific importance every year. The whole drama of the upward crawl of life is now found to be vitally connected with the periods of intense cold through which our globe has passed in former ages.

I offer here as a supplementary study to my earlier popular accounts of evolution (*The A B C of Evolu-*

tion and *The Evolution of Civilization*) a plain and non-technical account of these Ice Ages and how we know them, with particular attention to the human interest of the subject.

J. M.

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CHAPTER I

ICE AGES AND DARWINISM

THE story of the Ice Ages belongs, in more senses than one, to what is called the romance of science. Less than twenty years ago there still circulated in England a work in which a clerical geologist cheerfully, in fact contemptuously, dismissed "the great Ice Age" as "the great nightmare." He appealed to the authority of a very distinguished and very aged geologist, who, not finding any reference to Ice Ages in the first chapter of *Genesis*, succeeded in closing his purblind eyes to the evidence that was pouring in from every quarter of the globe.

The last faint traces of this curious prejudice have long disappeared. The nightmare has turned out not only one of the most solid of realities, but one of the most powerful and important agencies in the onward and upward progress of life. There have been five great Ice Ages—or four definite Ice Ages and one long period of very severe chill—in the story

of the earth. Four times at least in the course of the earth's evolution the temperature of a region that measured millions of square miles slowly and steadily sank until the summer sun was not strong enough to melt the winter's snows; and the snows gathered, hundreds of thousands of feet thick, on the lower slopes of the mountains, and hardened into ice; and the ice sluggishly flowed, in deep rivers or glaciers, down into the valleys and far over the plains, and sometimes spread in a vast cake or "cap" that covered a whole continent. Far beyond the actual ice-field, moreover, was a fringe of territory, hundreds of miles broad, which shivered, as northern Siberia does to-day, in the biting winds and blizzards that hurried from the ice towards the warmer lands. For tens of thousands of years at least, possibly for a quarter of a million years or more, some vast area of the earth's surface was thus converted into a desert of snow and ice. That is, briefly, an Ice Age.

But I have mentioned northern Siberia, and it will at once occur to the reader that the preceding paragraph is just a picture of our polar regions to-day. The ice-caps at our North and South Poles cover more than ten million square miles, and round them is a broad, bleak fringe of wintry territory. Does this mean that we are living in an Ice Age to-day? A frivolous person might add, seeing that we have laid stress on Ice Ages as means of progress: Do you ask us to believe that the lowly Eskimo and the dull

Siberians, who enjoy the bracing winds from the ice, illustrate the way in which Ice Ages contribute to the advance of life?

The questions will help us to fix more precisely the part that the Ice Ages have played in the drama of earthly life. The polar ice-sheets of to-day are actually far larger than the sheets which we can trace in what we call the Ice Ages, yet they clearly play no part of any importance in the evolution of life—at all events, in the evolution of *human* life, for there are very interesting developments, due to the glacial conditions, in the animal world. Man in those regions is so absorbed in wringing a scanty diet out of the stingy earth that he has no time or brain for anything else. We regard the polar regions as deserts, as so much waste land, on which the living things of the earth might, if it were green field or forest, get on with the drama of their evolution.

But suppose these icy deserts had once been warm and fertile areas, with abundant and luscious vegetation and teeming animal populations. Suppose these teeming animal populations had had easy conditions of life—warmth and plenty of food—during millions of years, and had become sluggish and unprogressive (or very slightly progressive), as animals do in such circumstances. And suppose the glacial conditions had crept slowly during tens of thousands of years upon this sluggish population. Any person can see that, if this is the real history of the polar

ice-caps, they may *at first* have provided a mighty stimulation of the living population.

That is, in point of fact, what happened. In the rocks of the Arctic and Antarctic circles we find the remains of the animals and plants of earlier days, just as we find them in the rocks of other regions. Two or three million years ago those rocks were beds of mud or sand, and the bodies of animals and leaves of plants got buried in them occasionally. The beds were hardened into stone and the remains "fossilized"; and the geologist who accompanies arctic explorers learns from them the earlier history of the polar regions. Two or three million years ago Greenland was as warm as Algeria is to-day. Graceful bamboos, gorgeous magnolias, even fig-trees, flourished where a vast sheet of ice now eternally buries the land. There are high authorities who regard the region as actually the cradle of the great monkey, ape, and human families. At all events, the glacial chill came gradually upon a warm-loving, well-fed population; and there was "natural selection" in its grimmest form. It was the beginning of the last Ice Age.

In order that the reader may have at the outset a clear idea of what we mean by the Ice Ages, I must anticipate a little. We say that the Ice Age is over, yet these vast ice-caps linger in the polar regions. What is the meaning of that?

We shall see that after each Ice Age the earth

returns to a genial climate, but *not to the temperature it had had before.* The globe is growing steadily colder. Ice Ages are temporary periods of intense cold for certain parts of the earth; but, apart from them, the globe as a whole is "running down," as it were, in point of temperature. Until the oncoming of the last Ice Age there was no such thing as really permanent ice or snow anywhere on the earth. There were no polar caps. Now the poles are permanently frozen, and as time goes on—as millions of years go on—the ice will slowly extend towards the Equator. We have every reason to know that in time the whole earth will be permanently frozen over. So marvellous and sure is the vision of modern science that we can, if you wish, go even further. Long after all the water on the globe is permanently frozen solid, the atmosphere will begin to liquefy. The temperature will sink to two hundred degrees (Centigrade) below zero, and then our atmosphere will be a sea of liquid air, thirty-five feet deep, lying upon the solid ice in our ocean-basins.

But that will be long after "the fretful hour" of man is over, and we will confine ourselves to the Ice Ages of the past. Cold will one day extinguish all life on this globe, but in its earlier stages this advancing cold will have done much to stimulate the progress of life. We used to think of life in the past as a great battle of one living creature against another, for food or mates (among the higher animals). We saw that

a comprehensive, world-wide struggle of this kind would test the strength, the speed, the cunning—the life-qualities generally—of animals, and would, by eliminating the weaker or more sluggish, tend steadily to improve the standard or change the structure in each generation. So we said that "natural selection" was the great agency of Evolution, as the genius of Charles Darwin was the first to discover.

This "struggle for life" is one of the most obvious and elementary facts. It is going on to-day in every field and pond, every mile of the ocean and every mile of the land's surface, every workshop and every football field, every profession and every system of ideas, even among Churches and States. In these latter days social or intelligent evolution tends to take the place of evolution by combat, but throughout the greater part of the development of life on the earth there was *no* social or intelligent evolution. One has only to look round and see how pitifully feeble social evolution is in our own day, although that supposedly intelligent animal, man, has been on the earth for more than a million years!

We will return to this in the last chapter. For the moment it is enough to say that the "struggle for life," in the old sense, has been throughout the ages just as great a reality as Darwin thought. There have been a good many attempts to get away from the picture of "nature red in tooth and claw," but they are foolish. The teeth and claws would not be

what they are if there had not been a prodigious development of them by use.

But modern science has something further to say. Every year thousands of new facts are gathered in the field of nature and sent in to what we may call the "clearing house"—the universities and learned societies. So our general picture of nature is enlarged or modified every decade. In the present instance we have not lessened our idea of the struggle in nature. We have enlarged it. Underlying and overlapping all the struggle of individual animals against each other, there are two great struggles of the elements. One is the battle of land and water. From the dawn of time that battle has been waged—in one age the oceans flooding millions of square miles of the land, in another the land rising like a giant and shaking the waters from its broad shoulders.

That has had in every age an enormous influence upon the struggle for life of the little pygmies, the animals and plants, that lived on the land or in the water. It has involved myriads of revolutions in their conditions of life, and these have sternly tested their life-qualities. But we are not concerned here with this war of land and water, except that we shall see that it is the rise of the land that explains Ice Ages.

The struggle of the other two elements, heat and cold, is not less eternal and important. The cold of space—about three hundred degrees below zero

(Centigrade)—is like a great dragon lying in wait for every globe in the universe. For millions of years the globes remain hot enough to keep it off. A star may blaze for a thousand, or even several thousand, million years, but the dragon will close in on it in the end. Planets may bask in the heat and light of the suns for tens or hundreds of millions of years; but, as the fires of the sun sink, the dragon closes in, and the living populations of the planets pass into the silence. The fires of our sun are sinking, and the dragon is slowly approaching. (But be not alarmed. There are probably some tens of millions of years still for man on this planet.)

What we have discovered in tracing the Ice Ages is that the dragon may get its teeth in, so to say, prematurely and temporarily—for a matter of a quarter or half a million years. To keep up my little allegory—if the reader is not tired of it—the dragon seems to be watching the struggle of land and water, and every time the land gains a great victory, every time it rears its head too high above the sea level, there is a long spell of severe cold. There have, as I said, been five such periods of what we may call the first-class order: five Ice Ages. But there have been numbers of smaller uplifts of the land, followed by corresponding local chills. There have, in other words, been five revolutions in climate, and a large number of minor disturbances.

A revolution in climate, a change from great warmth

to arctic conditions, is bound to have a profound effect upon the living population. From millions of square miles the population disappears, and in further millions of square miles the vegetation is entirely changed and very greatly impoverished. There is a struggle for food, a vast destruction of life from cold and hunger, a demand for new habits and new organs. But all this will be fully explained and illustrated in later chapters. It is enough for the moment to say that during an Ice Age the living population of a very large part of the earth passes through a long and terrible ordeal. A very large proportion of it is annihilated. A few types survive by developing new structures or habits to meet the cold conditions; and we shall see that in a considerable number of cases these changes mean a very important advance in organization.

Now all this is a splendid enforcement and development of Darwin's fundamental idea. Darwin wrote more than fifty years ago, which is as much as to say that he was certainly wrong on many points. The most distinguished man of science of our own day would laugh at the idea that he is right on every point—that time will make no change in the brilliant theories which seem to him to give the best explanation of the facts as we know them at present. Fifty years ago the facts were not known nearly so well as we know them to-day. The progress made in *observation* in half a century is colossal. Moreover, Darwin

was a pioneer in a new field of speculation. For twenty years he worked without any check of criticism whatever upon his ideas.

In the circumstances it is marvellous how right he was. The man who would try to prove him right in everything would be as foolish as the man who cackles because he was wrong in some things. It is, however, interesting to know that the main position taken up by Darwin was sound. Even distinguished men of science have in recent years spoken as if "Darwinism" were dead and natural selection discredited. The general public is puzzled, and a few words on the subject may be welcomed.

If Darwinism means anything, it means that the various species of animals and plants were evolved by means of natural selection. Darwin, a very retiring and diffident man, would not have cared to see any scientific gospel set up with his name attached to it; but, if he were asked to give the essence of his theory, he would simply have quoted the title of his great work: "The Origin of Species by means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life." There is no need to say what that means. In every generation the individuals differ greatly from each other in strength, health, speed, cunning, sight, and so on. The destructive agencies of nature weed out the less gifted, and so "preserve" or "select" the better endowed. Thus the type is progressively changed.

In working out this theory Darwin relied on two beliefs which have since been sternly challenged. He thought that what are called "acquired modifications"—for instance, changes of organs acquired by the individual during life by the use of those organs (like the strength of a footballer's leg)—might be handed on to the next generation. This is now generally denied, though there are eminent men of science who still hold it; but it is not an essential part of what any instructed person would call Darwinism. It was the general belief of scientific men in Darwin's time.

Secondly, Darwin thought that progress in the making of new species was very slow and gradual. For instance, the power of a hawk's wing or the keenness of its eye was developed by *very* small increases of strength and keenness during a long series of generations. Most people would still think the same *in this case*, but there are other changes which are not so easily explained. A new theory, Mutationism, has arisen, and it demands larger changes (from parent to child) than Darwin generally admitted. In his own book he recognized "abrupt and great variations," but he thought that they were rare. That question is still undecided. The new theory has its difficulties and weaknesses, and the public ought not to be intimidated by the dogmatic tone of some who write on it. It is not yet established, but it is the more favoured theory.

These are the real corrections, or possible corrections, of Darwin. His fundamental teaching is sound. Some men of science of our day have evidently never read Darwin. They talk as if he did not know that natural selection is, as far as new species are concerned, negative. What nature positively *does* is to destroy the less fitted to survive. It is a sort of poetry to say that nature "selects" the fitter. How any one can suppose that Darwin did not see that is puzzling. He doubted himself if the term was the best possible, but he wrote to A. R. Wallace that, "with all its faults," he could see no better.

Others point out that natural selection is "not omnipotent," or not the only cause of evolution. As if Darwin had said that! On June 5, 1860, he wrote to Hooker:

> "I have never hinted that Natural Selection is 'the efficient cause to the exclusion of the other'—i.e., variability from climate, etc. The term *selection* implies something—i.e., variation or difference—to be selected."

In 1865 he wrote again to protest emphatically against the idea that he "attributed nothing to variation independently of Natural Selection."

These passages, finally, answer the writers who say that Darwin looked only to action from *without*, and did not realize that the agency *within*—which causes the variations—is equally important. He wrote to

Hooker in 1857 that "external conditions do by themselves *very* little." He thought that external changes provoked changes in the animal, but he reminded Hooker "how profoundly ignorant we are on the causes of variation." In his last years he was very busy with this "most perplexing problem," and he confessed that it "baffled" him to the end. He was very far from ignoring the problem of the origin of the variations which nature "selected." But embryological science was still imperfect when he died. In fact, it is still very obscure on that side. Mendelism has thrown much light on the machinery, but it is not yet established as a general theory.

This little account of the rights and wrongs of "Darwinism" may be useful to some readers. The truth is that Darwin left open, all his life, the question what agency caused the young to differ from their parents. His great theory was that such differences, however they arose, were the material for making new species, and that the machinery which made new species out of them was natural selection. That is, if one may say so, truer than ever.

Instead of the work of natural selection being reduced to more modest proportions by our discovery of Ice Ages, it becomes more important than before. They are natural selection in its most imposing form. It is as if the agencies of nature took the population of a whole continent and put it through a drastic and searching test for a hundred thousand years. Let

me illustrate it by anticipating one point. In the fifth chapter we shall see that the age of the Coal Forests ended in an Ice Age. This affected a continent which then stretched from India to Australia and South Africa. At the beginning of the Ice Age the highest animals on this continent, or anywhere in the world, were clumsy reptiles. By the close of it some of these reptiles had evolved into mammals and birds, and the overwhelming majority of the animals had been annihilated. If that is not natural selection—whatever view we take of the embryonic machinery—the word must have a new meaning. It is, at all events, precisely what Darwin meant.

Three times since the first living things quitted the ocean and began to flourish on the land, the population of the earth has passed through one of these mighty selective ordeals. At the close of each, new and higher types of animals and plants were found on the earth; and no one would be quite so foolish as to say that it was a mere coincidence. There are some—mostly philosophers, but a few men of science—who would attribute evolution to an internal principle, a "vital principle," which has worked steadily up from the lowest level to man, moulding matter to its successive designs. It is hopelessly unintelligible how a principle which is unconscious, and therefore acts blindly, can be credited with such work; but in any case it does not lessen the action of natural selection in the great Ice Ages.

Furry and feathery things, with warm blood, appeared during an Ice Age, because the condition of the world permitted and favoured them, slaying their fur-less and feather-less rivals. The hardy pine and yew and fir appeared during the same Ice Age for the same reason. The great reptiles of long ago quitted the earth because an Ice Age slew them; and, as this left the Northern Hemisphere to the higher birds and mammals, they were "selected." The oak and beech and holly came during the same Ice Age for the same reason. Finally, man was brought to face the same stern test of an Ice Age, and we shall see that it put him on the path of progress.

This is the story we propose to tell, once we have explained how we know of these Ice Ages, what caused them, and at what precise points in the earth's chronicle they occurred. There is only one further preliminary remark to be made.

I have occasionally spoken of the Ice Ages as "revolutions," and some will wonder whether this is not a frivolous use of words, if not an outrage on the dignity of science. Well, the word is not mine. It is the word applied to Ice Ages by the leading geological writers of our time. They were revolutions in climate. Before each of them the earth had been for millions of years innocent of ice and snow, of glacial currents in the ocean and deadly blizzards on the land. That is an essential point to bear in mind. The Ice Ages supervened upon long periods of what

we might call perpetual summer. They came upon a population softened by long indulgence, by millions of "years of plenty." That is why they were so effective.

They were revolutions in climate, and in a sense they were revolutions in biology. Here some horrified reader may wonder if science is now adding to its misdeeds by encouraging "Bolshevism." Have we not been told for decades that on the social side the message of science was emphatically, Evolution not Revolution? Science was supposed to know the laws of life intimately, since it embraced fifty million years or so of life-development. And we distinctly understood from it that the fundamental law was: "Slow and steady progress." We were to advance by inches—nay, millimetres—not yards. What are we to say to the young man in a hurry who gets hold of one of the most authoritative manuals of modern geology—say, by Professor Chamberlin or Professor Schuchert—and finds the dreaded word "Revolution" used repeatedly, if not standing for the very greatest advances that have been made in the march of life?

I have just said that Darwin's idea of minutely slow and gradual change is very much challenged to-day. It is not merely the geologist who departs from the old idea. Mutationism is very widely accepted, and it means that progress takes place by larger changes ("mutations")—longer steps, as it were—than Darwin thought.

What the geologist means, however, is something different. He may be either a Darwinian or a Mutationist. He may think that the transformation of a reptile into a bird was accomplished by adding together a series of dots or a series of dashes—to make an illicit use of the Morse code. That is nothing to him, and we are going to imitate him in his work. When he speaks of "revolution," he means more rapid evolution than had preceded.

There is really no antithesis between evolution and revolution. All the changes that take place are evolution. The French Revolution was a piece of political evolution. So was the Russian. But there is slow evolution and rapid evolution. Science now recognizes that life has by no means advanced at an even pace. During Ice Ages, particularly, the pace of advance has been much more rapid than during the "golden ages" which went before them. Man, for instance, made more progress in the last fifty thousand years of the last Ice Ages than during the first million years of his existence. It was a revolutionary period.

Yet let not the social student rush to conclusions. The revolutions of which we speak in geology are portentously slow, if we measure them by human standards. The whole story of human civilization is, in the most liberal estimate, a matter of ten thousand years. You might, by a stretch of imagination, call that entire story a revolution—a revolt of intelligence

against the stupid older order. Yet this long period is not one-tenth as long as an Ice Age. That is where any attempt to make a parallel with man's affairs fails. But we will return in the last chapter to these questions of social philosophy, which arise out of our subject, and will now proceed to tell how we know that there were Ice Ages in the past.

CHAPTER II

HOW WE DISCOVER ICE AGES

THE first difficulty that occurs to the unscientific person who is told about Ice Ages is that he cannot see how we can possibly know of changes of climate in former days. It is difficult enough to say whether there has been any change in the climate of England during historic time. We get a reference to it once or twice in a century—in Pepys's Diary, or in some incidental notice of the weather in a chronicle of war—but we have very little knowledge of it even for the last thousand years. How, then, can we say confidently that there was an Ice Age in Europe a quarter of a million years ago? How are we to believe Australian and Indian geologists who announce that there was an Ice Age in their countries some ten million years ago? And what a feat of imagination it must be for Canadian geologists to assert that they can trace one of these revolutions in climate fifty or more million years ago?

So talks a certain type of man in the street. The truth is that some of the statements of science which seem to him most clearly beyond the power of the

mind are reached by methods which are really simple and positive. We say that light travels at 186,000 miles a second, and that 700,000,000,000,000 waves of it enter your eye in a second when you see a violet. We say that the earth weighs 6,000,000,000,000,000,000,000 tons; that very few of the stars are less than 100,000,000,000,000 miles away; that a certain "new star" was a blaze of white-hot hydrogen gas, several hundred billion miles away, flaming outward at a speed of a thousand miles a second. We say that electrons travel at (sometimes) more than 100,000 miles a second, and that the nucleus of an atom of matter is about the billionth of a centimetre (which is about two-fifths of an inch) in diameter. The thoughtless person rolls his eyes, as if he knew more about the rules of evidence than our best men of science do. Yet in all these cases the evidence is exquisitely simple—it can be explained to anybody—and conclusive. It is far easier to prove these things than to prove that there *are* any stars, or even that there *is* an earth.

The evidence of past Ice Ages is even simpler and easier. Some years ago I visited Switzerland and was particularly interested in one of its ice-rivers, or glaciers, which is called the Rhone Glacier, because the stream of water which flows from it, as it melts, is the beginning of the river Rhone. You go up a broad valley, fifty miles long, from the Lake of Geneva. Steep mountain sides, with a glacier or a snow-field

gleaming here and there on the crests, enclose the valley; and all the way along it are piled huge mounds of a peculiar bluish-grey rubbish, with large stones of every shape and size mixed in beds of coarse dust or what looks like soil.

At length the side-walls of the valley gradually close in, and you reach its head. Before you a cascade of ice, a frozen Niagara, hangs over the ledge of the higher crest and tumbles, in masses as large as houses, all crushed together into a giant stream, down to the floor of the valley. It moves so slowly —a few feet a day—that it seems frozen to the mountain-side; but, if we tracked the stones on it month by month, we should see that it *does* move.

And here you get the secret of the great mounds that sprawl the length of the long valley. The ice is from fifty to several hundred feet thick. Where it is 200 feet thick we can calculate that it lies on its rocky bed with a pressure of 500,000 pounds to the square yard. In other words, it is a colossal scourer, weighing millions of tons, slowly grinding down the mountain-side. Suppose we set a mass of steel weighing millions of tons travelling by its own weight down the slopes of the heights above London. Suppose some agency kept this sluggish but powerful river of steel flowing for tens of thousands of years. Houses and soil would soon go, then the moving mass would begin to scour the rocks (if there were rocks below) into fine powder, and carry it to the valley below.

That is what the glacier does. The water that streams from it at the melting-point is a sort of muddy blue with this powder. Mounds of the dust lie about, and are continuous with the mounds down the valley. You notice also that the ice bears stones of all sizes on its surface, near its edges. Looking up the glacier, you see why. As it passes under the cliffs, the stones fall upon it from above. The sun is just as powerful in the snow-fields as in the valley—more powerful, as I found when it scorched all the skin off my face. It melts the surface of the snow and ice, and water trickles during the day into every crevice. At night the water freezes and expands, breaking off fragments of rock that go down upon the glacier. They mingle with the dust of the scoured rocks where the ice melts.

Many of the stones slip through the great cracks or crevasses in the ice, and reach the lowest part of the ice-river. You can imagine what happens. As the glacier moves, they are driven into the rocky floor of the bed by a pressure of half-a-million to a million pounds to the square yard. This will make scratches or furrows in granite rock. The whole bed of the ice-river is scored by the marks of its flow. It is as if the river of steel which I imagined were studded with steel teeth on its lowest side. They would plough, or rather harrow, granite.

So this Rhone Glacier, which we are studying, does three things. It marks its bed with scratches

and furrows, in one general direction (the direction of its flow), which will last for ages. It leaves a mound (or "moraine") of a peculiar and easily recognized rock-dust, as we may call it, at its melting-point. It mixes with the dust the stones, large and small, which it has collected in its passage.

Now we begin to understand the fifty-mile valley up which we go to find the glacier. It has similar mounds of mingled dust and stones all along, though they are immensely larger than the mound at the foot of the Rhone Glacier. It is grooved and scratched and furrowed, in a consistent direction (down the valley), all through. There can be no mistake whatever about the conclusion. The whole valley was once filled by a giant glacier. The comparatively small Rhone Glacier of to-day once ran the whole length of it, and was joined by similar streams of ice from every side-valley until a vast solid river of ice, in places ten miles wide and more than a thousand feet deep, filled the whole valley.

At the end of the valley is, as I said, the broad blue face of the Lake of Geneva. Something has carved out of the solid surface of the earth a basin forty-five miles long, and in places a thousand feet deep. Again, there can be no mistake about the cause of it. It was the vast glacier that came down the Rhone Valley at some remote date. If a very ponderous mass is moving down a slope and it at last touches level ground, it will naturally strike this level ground

with a greater pressure than ever. It will wear a little hollow at the point where it ceases to travel downward and encounters the horizontal strata. And if your mass weighs millions of tons, and keeps on scouring for tens of thousands of years, it will in the end scoop or gouge a great basin out of the solid crust of the earth. When the ice melts at last, the basin will fill with the waters. The lake is another reminiscence of great glaciers of long ago.

By means of the scratches and scoured rubbish and stones transported from distant hills we can trace this huge glacier of long ago about two hundred miles further across the plains of Europe. And it is the same on every side of Switzerland. The valleys up which we pleasantly travel to-day were once filled with ice. They were mainly carved by ice. The lake-basins were hollowed out by the ice. The Lake of Lucerne, and especially the Italian Lakes, mark sites where colossal ice-rivers struck the plain age after age. On the Italian side the slopes along which the glaciers moved are steeper, and the lake-basins are deeper and grander. Every feature of the scenery becomes intelligible.

We now know the chief means by which we can recognize regions where there was once very thick ice—which means ice summer and winter—and is no longer: scratches and furrows in a generally consistent direction, great mounds of dust scoured off the rocks and including blocks of stone from distant

mountains, and lakes of the kind we have described. We apply these to the Swiss district, and we learn that at one time a mighty cap of ice and snow covered the whole country and stretched far beyond it. We can prove, in fact, that 15,000 feet have been scoured off Mont Blanc itself since it reached its greatest height. The Swiss snow-fields and glaciers of to-day are shrunken remnants of the former sheet of snow and ice.

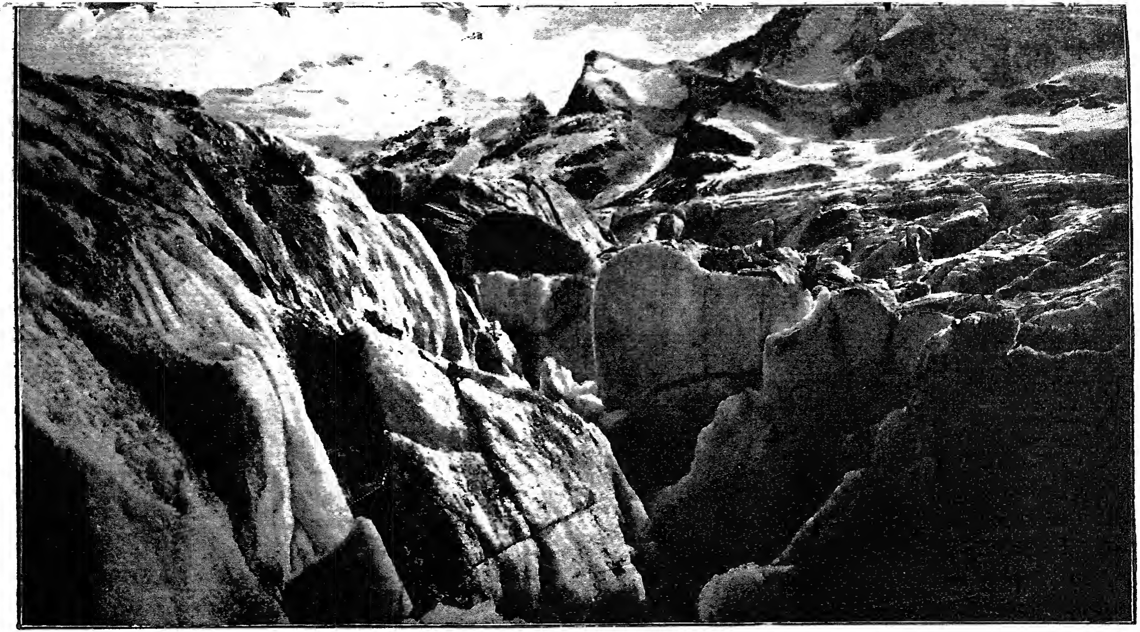
It is by precisely the same means that we can tell that, at the same time as Switzerland wore its huge ice-cap, eight million square miles of Europe and America were covered, summer and winter, with ice and snow, and every high range of mountains on the earth had a corresponding ice-sheet. I once travelled on a stage-coach through a valley in New Zealand —Arthur's Pass—which corresponded with the Rhone Valley in Switzerland. It was a wide gorge cut through the rocks by a great ice-river long ago; and the little glaciers which hung upon its crests, and even the large glaciers of the New Zealand Alps beyond, were diminished relics of a period of far more extensive ice and snow. The fiords of New Zealand, like the fiords of Norway, are other relics. They are the tracks cut in the raised and rocky coast by great glaciers of long ago. They were carved by ice—the work in each case being afterwards completed by water—just as were the valleys of the Alps. In South America and other parts of the world we have similar

memorials of ice-action on a vast scale in the recent history of our planet.

But it is especially in the north of Europe and of North America that we find such memorials. I have mentioned the fiords of Scandinavia. Looking up some of the more northerly of these fiords, you still see a comparatively small glacier at the head of the valley. It is, like the Rhone Glacier, the shrunken survivor of a colossal glacier of long ago, which carved the fiord.

The plateau of Scandinavia was plainly at one time a vast snow-field such as we now find in the Arctic. Summer and winter the snows accumulated. The sun would melt only the surface, and the water trickling or soaking down into the condensing snow helped to convert it into a mass of ice; as happens in the snow-fields of Switzerland to-day. The ice moved bodily, thousands of feet deep, to the lower level, breaking into rivers or glaciers, which poured through every gap at the edge of the plateau, widening and deepening each gap until it became the beautiful valley which we now call a fiord.

How far did these colossal glaciers of Scandinavia go? One of the ways in which we can retrace their paths is, as I said, by means of the blocks of stone which they gather from their native mountains, and bear along until the ice reaches its melting-point. Now, it was noticed long ago that the east coast of Scotland is strewn with great blocks of stone which



CREVASSES ON A GLACIER

Reproduced (by permission) from *The Building of the Alps*, by T. G. Bonney. (Fisher Unwin.)

certainly came from Scandinavia. How explain this mystery in the old days?

One clerical writer, who would have none of this nonsense about an Ice Age, said that the blocks were probably brought by the Vikings, as ballast for their boats, when they descended upon the coasts of Scotland! We now see, of course, that they were brought by ice. It is not yet entirely settled whether they were brought by icebergs floating in what we call the North Sea or by glaciers. The general opinion is that the North Sea did not then exist, and the Scandinavian glaciers spread a huge sheet of ice as far as Scotland, four hundred miles away. We trace the glaciers in the same way over Denmark and Germany.

But Scotland, we find, had at the same time its own glaciers, and they were far more formidable than any of the two hundred glaciers of modern Switzerland. Some were three thousand feet deep. They poured sluggishly down from the higher Caledonian mountains, some of them passing along the valley which is now the Irish Sea as far as North Wales. From the hills of Cumberland and Westmoreland flowed other glaciers, helping to complete the mantle of ice over northern Europe. The English lakes, generally, fill basins that were carved in the earth's crust by the glaciers of the district; just as the Scottish lochs, generally, also mark spots where the moving masses of ice touched the plains. In other cases valleys

were dammed by mounds of glacial rubbish and converted into lakes. The Welsh mountains were another great snow-field that poured immense glaciers over the country.

Over all these areas we have the same unmistakable evidence: smoothed and scratched rocks, hollowed-out lake-basins, blocks of stone from remote mountains, and especially the huge beds of mingled scour-dust and stones which geologists call "boulder-clay" or "Drift."[1] Within one recent month I had occasion to travel along four or five of the valleys of South Wales, and in Lancashire, Northumberland, and Scotland. In each district the railway-cutting showed mile after mile of glacial rubbish; and I have noticed the same from the train in the United States, from New York to St. Louis, from Detroit to Niagara. It underlies the soil over immense areas of North Europe and America.

It is interesting, as one travels, to find oneself flying in a modern train through miles of country where once vast glaciers laid down their burdens of rubbish. A man can recognize it almost anywhere; it is so characteristic. It is interesting to stand on the hill-tops in England, Wales, or Scotland, and

[1] The Drift (mixed mass of dirt and stones or boulders) is generally called "Till" if it lies as it was originally. But the flooded waters at the close of the Ice Age have largely redistributed or "stratified" it. That is why the boulders are so commonly rounded, as stones are in running water. The actual mound left by the glacier is called a "moraine."

trace the paths of the great ice-rivers which did most of the carving of their valleys, or to mark the boulders, scattered over green valleys, and picture the stream of ice that bore them ages ago. But the systematic work of carefully examining each of these regions and piecing them together in a comprehensive map of the glacial area has been done long ago by geologists. At some time within the recent geological period eight million square miles of Europe and North America were covered with a sheet of ice and snow, summer and winter, such as we find in the Arctic Circle to-day. In Europe, generally speaking, the ice-sheet spread down nearly to the latitude of the Thames and the Danube; but we have quite lately discovered that there were small glaciers even on the South Downs at that time.

In America the sheet was even larger than in Europe. The great lakes were hollowed out by enormous glaciers moving down from Canada, and the marks of the ice are seen much further south. Within ten miles of New York one sees that the railway-cutting is ploughed through a bed of glacial rubbish. The indications are the same everywhere. The soil was scoured off vast areas, and their rocks were rounded, smoothed, and scratched. Older streams found their paths barred and were turned into new courses. Boulders and boulder-clay are found on all hands.

We have spoken of Switzerland, but Greenland

gives us a better picture of what northern Europe and America were like at this time. Glaciers suggest comparatively narrow streams of ice, rarely a mile wide, though there is one in Alaska, the Malaspina Glacier, which has a coast-front seventy miles in width, and is more than 1,000 feet thick. But there may be lakes or seas of ice as well as rivers. In Greenland the sea or "cap" of land-ice covers half-a-million square miles, and it is often five hundred feet deep. Such caps there must have been in Europe and America. On the other hand, we do not imagine ice-caps or glaciers everywhere. As we shall see later, the reindeer, the mammoth, and the wool-coated rhinoceros were able to live in Europe. There were grassy or mossy regions. But we must remember that, in the height of this great chill, the reindeer and mammoth wandered as far south as the foot of the Pyrenees and the Alps. Even southern Europe and the southern United States must have then had a climate like that of Lapland or northern Siberia to-day; and the influence of the great chill, the cold winds from the ice-fields, would extend still further south.

These things will concern us later. We are interested here only in the huge sheet of ice and snow that for tens of thousands of years covered half Europe and North America. It was the last great Ice Age. It is humorous to recall that even a geologist of distinction could call this a "nightmare" twenty

years ago! There is no more certain event in geological history. The lingering hostility to it is only one more instance of the folly of resisting science on non-scientific grounds.

We discuss the causes of the Ice Age in the next chapter, and its remarkable influence on the evolution of man in a later chapter. But the reader will urgently ask *when* this Ice Age occurred. Here, unfortunately, science has no confident answer. The geologists of Scandinavia have recently made a very careful attempt to settle when the glaciers of their country retired to their present positions. They tell us that it was about 30,000 years ago, and this is generally accepted as "the end of the last Ice Age." But since we do not know how slowly the ice retreated northward, this does not help us very much. The Ice Age was over in France before it was in England, and in England long before it was in Scandinavia.

Probably most of the authorities would agree that, whatever be the period of time during which this mantle of ice and snow covered Europe and North America, it was at its greatest extension between 50,000 and 100,000 years ago—possibly nearer to the latter. Here there is a difficulty that is not yet settled. Most geologists believe that what we call *an* Ice Age is a very long period—possibly several hundred thousand years—during which the ice spreads from the higher land and retreats to it four or five

times in succession, and that there were comparatively warm intervals between the successive advances of the ice. Some suggest that when the burden of ice became very heavy Europe sank a little under it; much as if you pressed in one side of a tight rubber ball. It is thought that this would mean a return of the warmer climate and the melting of the ice. Then, it is said, the crust—that part of it which we call Europe—would rise again, and be glaciated once more. Others deny this, and believe that there was only one great ice-sheet.

This unsettled question need not detain us. Whether there were previous and smaller extensions of the ice or no, there *was* that enormous extension which we have described. On that all are agreed. How long it lasted we cannot say. The estimates of those who believe in successive sheets of ice run up to 400,000 years (which Sir Arthur Keith adopts in his *Antiquity of Man*), and even larger figures. We will return to the point in the seventh chapter. There also we will consider if the Ice Age is quite over.

We have now given so fully the evidence for the last Ice Age that it is almost enough to say that, on the same sort of evidence, we find earlier Ice Ages scored upon the face of the earth. These mighty masses of hundreds of millions of tons of ice make an impression that the earth cannot easily erase. Naturally we do not find the evidence for earlier Ice Ages so abundant. The field of the Great War still

shows its ghastly scars, but the field of Waterloo, a little further north, shows no trace of the Napoleonic struggle except where men have artificially preserved the bullet-marks. The hand of millions of years of time has generally smoothed the wrinkles and scattered the mounds of the earlier Ice Ages.

But the deep grooves and scratches which moving ice makes may be buried under later deposits, and so be preserved. I went one day to a beautiful gorge in Victoria, some fifty miles from Melbourne, to see the traces of a remote Ice Age. No ice or snow is ever now seen, summer or winter, in the Werribee Gorge; but on the exposed hard rocks, beside the stream, I found the unmistakable furrows and scratches. High overhead, at the top of the steep side of the gorge, was a narrow seam of coal. Once a semi-tropical carboniferous forest had covered the district with its weird giant club-mosses and tree ferns. Upon this an Ice Age had fallen. The glacier from the higher region had carved this gorge, and on its floor were the marks, at least ten million years old, of the passage of the frozen load. Even granite rocks are to such glaciers merely as stiff soil is to a harrow.

Geologists in India and South Africa find the same marks on rocks which correspond, in point of time, to the glacial marks in Australia. It had then been the turn of the southern continent. We know from other evidence that India, Australia, and South Africa

were at the time connected by land. Apparently this lost continent was the main theatre of an Ice Age—one of the most deadly on record—in that remote period.

Two earlier Ice Ages are announced, and we will consider them in the fourth chapter. There was also, as we shall see, a period of such great and fatal chill, though with few marks of ice as far as we yet know, that it deserves to rank with the other four revolutions in climate. We may say, therefore, roundly, that we have discovered five Ice Ages. Apart from these we can detect occasional periods of cold that are very much more restricted in extent; but the crust of the earth has now been so extensively examined that no one expects to discover another Ice Age.

More than a hundred years ago the great German poet Goethe began to collect evidence of the last Ice Age. He traced the former extension of the Swiss glaciers over southern Germany, and of the Scandinavian glaciers over north Germany. A few other geologists—for Goethe was a close student of science—were picking up the traces in various parts of Europe. There they had lain for fifty thousand years, awaiting the birth of science in the eighteenth century.

To these men the discovery had an exhilarating novelty. They had found something new and interesting about the earth and its history. That the world

at large ridiculed them and their stones need not be said. That there were others who would have liked to burn them for suggesting that the earth was more than six thousand years old, or had ever worn this ridiculous mantle of snow and ice, need also not be recalled. Goethe worked on. But what a passion would have been infused into his work if he had known, as we know, the part that Ice Ages have played in the development of life! Fifty years later came Darwin. But even he had to quit the study before he could penetrate half the mystery of this procession of life through the ages which he so masterfully sketched. Ice Ages have helped to illumine it for us. We have at last learned how to read the hieroglyphs they have left on the rocks, as early civilized man left on his tombs and temples. Let us, however, first settle the problem of the cause of the Ice Ages themselves, which, experience tells me, is one of the earliest questions to arise in the mind of the learner.

CHAPTER III

THE CAUSE OF ICE AGES

As late as 1876 you will find Encyclopædias that make no reference to Ice Ages, as if these were foolish or malevolent dreams of cliques of scientific men who wanted to disturb the existing order of ideas. But by that time every impartial geologist knew that the last great Ice Age was an established fact, and the search for the causes of it had begun.

There is still a certain type of writer who insists that science, especially evolutionary science, *explains* nothing; that it only *describes*. This is little more than a play upon words. If we take such a phenomenon as an Ice Age and, after prolonged search and severe checking of our results, assign the causes of the Ice Age, most people will call this an explanation, in the ordinary sense of the word. It is, of course, open to any person to say that we are now merely describing the causes, just as we previously described the effects; though in that case we should have some trouble to explain what an explanation really is. I refer to the matter only because the way in which science has solved the problem of the Ice Ages is an

excellent illustration of the foolishness of this kind of talk. We shall see that modern geology has at last hit upon what we cannot doubt to be the real causes —to use strict scientific language, the antecedent conditions—of Ice Ages, and these will seem to the ordinary person all that he requires in the way of explanation.

The same point will serve to refute another rather foolish gibe at modern science: the one thing in modern life, the one achievement of the modern mind, which places us indisputably and immeasurably above any previous civilization. Science seems to the casual reader to change its teaching very frequently, and there are those who try to destroy our confidence in it on this ground. The gibe seems foolish when one regards the solid and unchanging structure of knowledge which science has built up in the course of a hundred years, or the way in which to-day it analyses with certainty the chemical composition of a star that is a million trillion miles away, or measures, and discovers the speed of, tiny particles (electrons) which are thousands of times smaller than the atoms of matter. The man who is urged in this way to distrust science need only look round the new world in which he lives—the electric lighting and transport, the medical and sanitary and chemical services, the cheaper commodities and luxuries from other lands—and he will exclaim, in the words of Sir Christopher Wren's epitaph in St. Peter's Cathedral: "If you seek his monument, look around you."

But we shall now see a very good instance of the kind of change which is constantly taking place in science. The man of science proceeds, in the explanatory part of his work, much as a criminal detective does. He confronts a problem, often with very slight clues. He makes various guesses or "theories" about the solution of the problem, and these he successively follows up and checks until he finds the true cause. We do not blame the detective, although he fails, perhaps, in a larger proportion of cases than the investigator of nature does.

The first idea that occurred to experts as an explanation of Ice Ages was that possibly the Poles of the earth shifted their position in the course of ages. The earth spins round, in space, like a huge top. It is a vast ball of metal, weighing six thousand million trillion tons, which, as the geography books politely say, "turns on its axis" once in twenty-four hours. We should prefer to say that it *whizzes* round on its axis; for the people who live at the earth's Equator are borne round and round at a speed of a thousand miles an hour. It is well known that the Poles are the coldest parts because the rays of the sun have to slant through a great thickness of atmosphere to reach those regions. They are reduced by filtering through the air, and they fall so thinly upon the Arctic Circles that they are unable to melt the snows even in summer.

Well, take the earth as a giant top. Suppose this

top did not always spin perfectly upright, as the boy's top does. Suppose it—very slowly, in the course of tens of thousands of years—leaned first to one side and then to the other. The boy's top cannot do this to any great extent—it does to some extent because its peg is fixed. The earth might conceivably alter its position considerably, and in that case the same points on its surface would not *always* be the Poles (or the regions farthest from the sun). The Poles would "wander"; that is to say, the ice-cap, the glacial conditions, would slowly shift from one region to another as the earth "wobbled" in space. Why not suppose that during the last great Ice Age North Europe and America were simply the polar regions of that time?

The theory was helped out by another supposition. The earth travels round the sun, not in a circle but in an ellipse (or, roughly, an oval path), and the sun is not in the centre of this ellipse, but nearer one end. It follows that at one end of its orbit the earth is farther away from the sun than it is in the other parts of its orbit, and it also travels more slowly when it is thus farther away from the sun. Now, suppose this ellipitical orbit were altered in the course of ages—suppose the two long ends were drawn out still farther—so that the earth got periodically at a much greater distance from the sun. The winter would gain upon the summer. The winter's long snows would not yield to the summer's sun, and you would

have the condition of an Ice Age. If you combine this theory with the preceding, whatever region of the earth happened to be the polar region at the time would have a *very* cold experience.

As a theory it is not without fascination; and readers of Mr. H. G. Wells' fine *Outline of History* will remember that he has incautiously adopted it. But it is as dead as Daniel in modern science. A brilliant American astronomer, the late Mr. Percival Lowell, called it "the astro-comical theory of Ice Ages." Astronomers themselves will not admit—Sir Robert Ball was the last to admit—such extensive wobbling on the part of our staid globe. Sir G. Darwin proved long ago that such wandering of the Poles has not occurred. Professor Barrell, probably the highest recent authority on the cause of Ice Ages, sums up the opinion of our astronomers in the words: "It would appear that the assumption of polar wandering as a cause of climatic change and organic migration is as gratuitous as an assumption of a changing earth orbit in defiance of the laws of celestial mechanics."

And the geologists want the theory still less than the astronomers do. If it were true, there must have been fairly frequent periodical Ice Ages; one living writer, who clings to the theory, speaks of Ice Ages every 35,000 years! On the contrary, there have been only five Ice Ages in a hundred million years or more. If the theory were true, moreover, there would be ice-caps on each side of the earth—North and South

Poles—during each Ice Age. No such thing occurred. When the continent which stretched from India to Australia and South Africa was glaciated, the opposite Pole of the earth was not. When the Northern Hemisphere was covered with ice and snow from the Urals to the Rocky Mountains, there was only a small amount of ice in Australia and a large cap (due to the mountains) in New Zealand—just as there was in South America and India. In no case were there two polar caps. In fact, as we saw there *were* no polar caps on the earth until recent times. Moreover, the ice-sheet of the last and greatest Ice Age was nothing like circular. It had an immense width—from the Rockies to Siberia (across Europe)—and a comparatively slight depth.

The theory was, therefore, generally abandoned twenty years ago. When it was started the geology of Ice Ages was very imperfect. It was possible to squeeze into the mould of the new theory the few facts that were known. Since then glacial geology has made enormous progress, and the new facts are quite inconsistent with the first guess. So, like the detective, we abandon the first supposition and try another.

We need not consider in such detail all the other causes that have been suggested. The idea grew up since no one of them seemed sufficient of itself, that the Ice Ages were due to combinations of various causes at particular points in the earth's history.

Some argued that, if you assume an intense period of volcanic energy at times, the atmosphere would come to have an immense fine screen of volcanic ash floating in its upper regions, which would keep off the rays of the summer sun. We know that there have been such periods, but they do not generally agree in time with the Ice Ages, and so here we have, at the most, a possible auxiliary cause.

Others suggested that the ocean currents may change. New York has what the Americans call "zero weather" for months in the winter, because a glacial current runs down the eastern coast of America from the north; and if a strong current of air—a violent wind—comes with it, a Londoner (as I have found) can hardly breathe at the lower end of Broadway. London, which is much further north than New York, not only has no zero weather, but during most of the winter it is quite temperate, because the British Isles are bathed by a warm current (the Gulf Stream) and the warm southwest winds which accompany it. There is actually a plan, in great favour with anti-British Americans, to change the course of the currents; and we should be frozen up every winter without our Gulf Stream.

The idea, therefore, occurred to some that such changes of currents, owing to changes in the configuration of the land, may have made different parts of the earth glacial at different periods. The chief objection to this is that during the greater part of the

earth's story there were *no* cold currents of air and water, for there was no ice nor snow. The glacial currents *follow* the setting-in of the Ice Age; they help us to understand something which has greatly puzzled geologists: why the polar regions remained warm, in spite of the slant of the sun's rays, until recent times. It may have been, as Professor Chamberlin has suggested, because warm currents from the rest of the earth helped to keep up their temperature.

The next cause suggested is much more plausible. Why is it colder on the top of a mountain than at sea-level? The rays of the sun, of course, are just as strong, or stronger, because they are less obstructed by the pure air. But, except in the direct rays of the sun, it becomes colder the higher you go. Height, as such, has nothing to do with the matter. It is the gradual thinning of the atmosphere as you rise which is responsible for the cold. We notice at sunset that the rays of the sun are far less powerful than at midday. We know that they are far less powerful in London or New York than they are "on the line." Everybody knows why. When the sun's rays slant they must pass through a thicker mass of air than when the sun is right overhead, and the air reflects or absorbs much of the heat.

The thicker the air, in other words, the less heat will get through. But this cuts both ways. A thick air will let less heat reach the earth, but it will also *let less heat pass away from the earth.* The mountain

top is cold because the thin air not only lets more of the sun's heat through, but lets it be reflected at once back into space. The thick air of a city at the sea-level lets less direct heat through, but what it lets through it retains at the surface very much more. And two impurities in the air are especially important from this point of view: the vapour of water and carbon dioxide (or carbonic acid gas).

As to moisture, everybody has had experience of the difference it makes. Moist, muggy weather makes a district very warm. The district is, as it were, wearing an overcoat in summer. At the same time, we must remember that the moisture is itself necessary for an Ice Age. One of the coldest regions of the earth, Eastern Siberia, is not glaciated. It is dry, and the summer sun can melt the light snowfalls of the winter. Greenland, on the other hand, is glaciated. It receives the moist winds of the Atlantic, which give very heavy falls of snow; and, although its mean temperature is much higher than that of Eastern Siberia, the snows remain and condense into an ice-cap and glaciers. Some scientific men have ventured to say that abundance of moisture is more important than cold for making an Ice Age. We shall see presently how to overcome this difficulty.

Carbonic acid gas, on the other hand, simply tends to keep the surface of the earth warmer. The more there is in the air the warmer the region will be, and vice versa. It has therefore been said that possibly

one of the greatest causes of change of climate in past time was a change in the proportion of carbon dioxide in the atmosphere.

This matter is worth considering a little more closely. At present there are, on the average, only three volumes of carbon dioxide to ten thousand volumes of pure air in our atmosphere. But suppose there was once, or generally has been, a far higher proportion! Clearly, in that case the great warmth of the earth in past ages looks intelligible. Now there is twenty-five times as much carbon in the sea and thirty thousand times as much in the rocks (chiefly in coal and limestone), as there is in our atmosphere; and the oceans and rocks have derived their carbon, directly or indirectly, from the air. Here we seem to get some light on the high temperature of the earth during most of its history; and if we suppose that at times the proportion of carbon in the air was reduced far below what it is to-day, we get a plausible theory of the cause of Ice Ages.

We have, in fact, a kind of third battle of the elements underlying the drama of life; and these things are really much more enlightening than "vital principles" (which are hopelessly unintelligible in themselves) or mysticism like Professor Bergson's. There is the battle of land and water. There is the battle of the constituents of the air. And there is the battle, connected with and based upon the other two, of heat and cold. The oceans and plants are constantly

absorbing carbon from the air, and the balance is restored at times by great volcanic outbursts, which belch dense volumes of carbon dioxide into the air. On the generally accepted theory of the earth's origin atmosphere began with a high proportion of carbon in it. There is a new theory which denies this; but both must and do admit great volcanic activity, recorded in the rocks, at different periods.[1]

But while we read in the calendar of the rocks of intense periods of absorption of carbon (such as the Coal Forests) and vigorous periods of discharge of carbon (by volcanoes), we do not find that they occur at such periods as to explain the five Ice Ages. It is true that one of the greatest of the Ice Ages comes just after the Coal Forests and the formation of much limestone; and this is exactly what theory requires. But the last and greatest Ice Age had these antecedents only in the scantiest degree—far less than the preceding Ice Age, which was so much less severe that we can give it the title of an Ice Age only by courtesy. So we must go further, and reserve this as a possible auxiliary cause.

[1] I should say that I am indebted for most of the material of this chapter, and much of the material of other chapters, to the brilliant American geologists, Professor Chamberlin, Professor Schuchert, Professor Barrell, and Professor Case; and that they all follow the new (Planetesimalist) theory of the earth's origin. which I do not accept. I cordially acknowledge my debt to the fine works, however, and refer the reader to them for furt*i* details.

Another theory is that these past variations of climate are due to variations in the emission of heat by the sun. We have made the curious discovery that our actual glaciers advance and recede over periods of something between thirty and forty years; and some suspect longer periods of between 500 and 600 years. It is thought that these periods mean periodic changes in the sun's radiation of energy; and, at all events, it is now known that there are periods of the maximum formation of sun-spots. But, as it is impossible to imagine how changes in the sun can account for *local* chills on the earth, I will not linger over this theory. The sun's radiation affects the whole globe.

When, fourteen years ago, I first touched upon this subject in one of my works, I found geologists in suspense between the suggestions I have given and one other, which they admitted only to the same rank: the elevation of the land. It seemed to me that the latter was the really fundamental cause of Ice Ages, and in all my works since I have so described it. We now have authorities like Professor Schuchert—I need not say that he is not likely to have read my popular works!—writing that "probably the greatest single factor is high altitude of the continents, with great chains of mountains which disturb the general direction and constitution of the air currents and the cean currents as well." Professor Case, Professor rrell, and other special students are of the same cc ion.

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There is really no longer any need for reserve in stating *the* cause of Ice Ages. Professor Schuchert has given us a diagram in which he combines a chart of known rises of the land in past time and a chart of cold periods (Ice Ages and minor chills) in past time. They correspond almost as closely as the fingers of a man's hand correspond to the fingers of a glove. The few discrepancies—and these relate only to minor and less known periods—are within the limits of possible error owing to imperfect knowledge. Every serious chill the earth has experienced came just after, and during, a rise of the land to a proportionate extent.

Coincidence is absolutely out of the question, and we have only to reflect a little upon the matter to see that here we have a real and most interesting explanation. Let us again anticipate a little. The period of the Coal Forests was closed by an Ice Age. Now geologists can tell what was the condition of the earth during the age of the Coal Forests. Apart from a few local dry areas, the land was overwhelmingly low, hot, and muggy. It was a land of steamy swamps and saturated forests. The air was foul with carbon dioxide and rich in vapour. It brooded sluggishly over the land, keeping in the heat which struggled through it to the sun.

We know that towards the end there was an extensive rise of the land, and we can easily work out the effect. Most people know how rainy Killarney is.

The reason is that the moist winds from the Gulf Stream reach the summits of the Kerry hills, and are cooled. The invisible particles of moisture then come together and form clouds, and the "clouds drop their fatness" upon poor Kerry (which suffers much consumption in consequence). In other words, mountains cause a circulation of the air and a precipitation of its moisture in the form of rain. Thus the higher lands which rose at the close of the Coal Forest period enormously lessened the proportion of moisture in the air in those regions—sent it back to the sea in rivers—and the heat of the earth could escape better into space. At the same time the Coal Forests and limestone beds had been for a million years or more extracting carbon from the air in great quantities—enormous quantities—and helping to thin the atmosphere. It was like taking two blankets off the bed of a man who was accustomed to have three. The earth shivered. There was an Ice Age on and around the highlands.

I must not give the reader the impression that all this is now quite clear and harmonious. We are, remember, talking about the climate of ten or more million years ago. There are difficulties. Here and there during the Coal Forest Age the earth was, locally, dry enough to form salt beds. In Australia the ice of the later period is sometimes found at what is now sea-level. It is for science to find exceptional conditions locally. The broad truth is that every

rise of mountains has been followed by a chill; and every Ice Age has been preceded by a great rise of mountain chains. We shall see this in later chapters.

Thus we combine what is sound in the various speculations I reviewed. The crunching or crushing of a large part of the crust of the earth into the folds which we call mountains would lead to great volcanic activity. The alterations of level would create new ocean currents and modify old. The moisture that had, when it was evenly distributed, warmed the earth is now gathered into clouds, which form rain, and later snow and ice. From far around the cold regions would receive the warm moist winds, and the heavy snows would pile up on the mountains and harden into ice. But these general principles will become clearer to the reader when we work them out in detail.

Most people who are unfamiliar with these matters have a quite exaggerated idea of the fall in temperature that is needed to create an Ice Age, and they thus make the problem more difficult for themselves. One naturally thinks, at first, that if Europe once enjoyed a perpetual summer, and then passed into a long Ice Age, the average temperature of the continent must have dropped something like fifty or a hundred degrees. It seems to be a question of falling bodily from a summer temperature to a winter temperature.

The fallacy is that we are taking the temperature of too small a region, or at particular times. When we

think of summer we think of particular spells of hot weather. When we recall winter we probably recall the very hard days when we in the south of England get a dose, brought by northeastern winds, of the climate of Russia. The *average* temperature is very different. The scientific man takes the average temperature over a whole continent, and can calculate how many degrees this annual average temperature must fall in order to give the conditions of an Ice Age. It is not easy, but the calculation has often been made, and there is now a general agreement that the necessary fall of temperature is only something between nine and eleven degrees. Let us say, roundly, ten degrees.

It is not difficult to see how a great rise of the land would bring about a change to this extent in the temperature of a whole continent. We have not merely to think of the elevation itself, which brings large areas up into thinner air, but of the effect upon the atmosphere and water-distribution of the whole district. Apart from the highlands proper, there will be broad stretches of land which were formerly flat and low, and therefore probably sodden with water, that will now be tilted, and the water will drain off. Winds will be created by the inequality of temperature between mountain and plain, the air above the warm plain expanding and rising, while the chilled air from the mountains will take its place. The warm moist air will replace the cold on the higher

levels and be chilled, and its moisture condensed into cloud. There will be a considerable lowering of temperature over the whole area. That will give in time the required fall of temperature, and the snow-laden hills will begin to pour their rivers of thick ice down upon the plains.

CHAPTER IV

THE FIRST TWO ICE AGES

It will be admitted that if we afterwards show that there was a considerable elevation of the land before each Ice Age—as we certainly can in the case of the later and more important Ice Ages—we have found a real explanation. Some people, however, will learnedly remind us that there is a distinction between "proximate" and "ultimate" causes of things. The profound person wants to know the ultimate causes. In the present case the demand is reasonable enough if we put it in a more familiar shape. We have explained the cause of Ice Ages. It was the rise of the land and the changes in the atmosphere involved by this. But what was the cause of the rise of the land?

Here, again, there has had to be a long course of inquiry, spread over several decades, and more than one attempt to solve the problem has failed and been abandoned. In geology the work of science is even more laborious and extensive than in other branches, because beyond the professional geologists (generally professors at universities) there is a vast army of

what we may call amateurs, who do material service. Every science has its large body of amateurs—fellows of the Astronomical Society, the Zoological Society, the Geographical Society, and so on—but in geology a larger proportion of them are real workers. The reason is that geology has to study minutely the whole face of nature. Every quarry or cutting, every gravel-pit or cliff, may yield something. So a country is practically divided up among its local geologists, who search every scar or cliff or exposed surface in their neighbourhood. The thinkers, the constructive men, the great geologists, have to sift the reports of all these local investigations, from all over the world, and pick out the important facts which will confirm or disprove theories.

It is well for the non-scientific reader to understand this labour. He is apt to suppose that the "theories" he reads of are just clever guesses made by a few men who work in libraries or laboratories. It would greatly surprise the general public to see one of these men at work. I was once in the study of a distinguished anthropologist, a professor at Cambridge, and he had an amazing library, in many languages, of books and reports on all the races and peoples in the world, published or sent in by men who had examined them. I found in the study of a distinguished geologist a similar mass of reports, from all parts of the world, on the particular section of the earth's crust (quite a small section) on which he was an authority,

besides a great collection of specimens of rock, often cut and ground into slices thin enough to be examined under the microscope and polariscope.

In a word, a theory in modern science is based upon a colossal amount of actual observation, all the world over, by tens of thousands of trained and devoted observers. It has to face a fierce fire of criticism from scientific men themselves when it is launched. There is, of course, a good deal of further criticism from non-scientific people, but no one who is primarily concerned about the truth of his opinions takes any notice of that, because it is always incompetent, and often ridiculous. Then, even when the theory is generally accepted, it is only "provisional" for a long time. It fits the facts at the moment, but new facts may disturb it. After a sufficient period it may have the same degree of certainty as the facts themselves. That is the position, for instance, of the theory of evolution. Millions of facts, in every department of nature, have been discovered since it was proposed, and all fit it perfectly.

The rise of mountain chains in former ages may seem to be so far from our experience that any theory of the cause must remain very speculative. But the matter does in some ways come under experience. For instance, when we say that the warm Coal Forest period in America ended in an Ice Age because a great range of mountains arose there, we have positive evidence that this was so. Ranges of mountains do

not vanish into thin air. They are ground up, by ice and water and weather, and the rubbish is laid by rivers on the nearest sea-floor. As we find such rubbish (now turned into rock once more) forty thousand feet deep at a certain part of the United States, we know that it represents the ground-down remains of a range of mountains, probably about twenty thousand feet high, which arose in America toward the close of the Coal Forest period.

Why was the crust of the earth thrown, or crumpled into these (and other) mountain masses? Well, just as we took Switzerland to illustrate an Ice Age, we may take it to illustrate the formation of mountains. The higher Alps are great stumps of very hard rock (granite, gneiss, etc.), which it takes a long time to wear down. We saw that the frost and flowing ice *are* wearing them down, and we know that millions of tons have been worn off them since the Ice Age. We know further that the stuff of which these granite and other mountains are made was once molten rock, which has solidified or frozen. It came up from the lower depths underneath the ordinary crust of the earth. It was originally, in its physical condition, like the lava that pours out of an active volcano.

Now, if we take two ranges of mountains in the Alps and examine the rocks under the soil of the valley which lies between them, we find a curious thing. The beds of sandstone, limestone, etc., underlying the soil of the valley are curled up—rather in

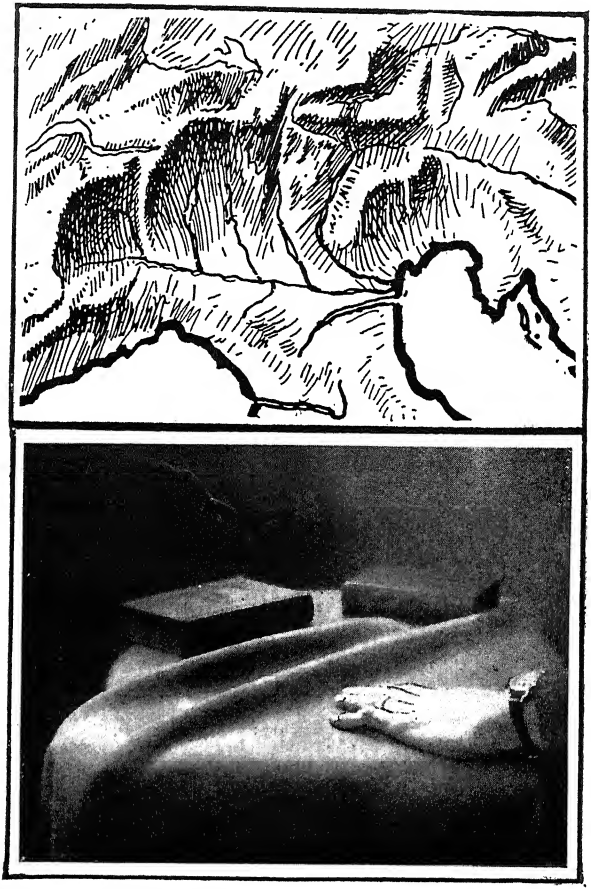
the shape of a great U—as if they were made of leather instead of hard stone. We then find the same thing in the valley across the mountains—the same rocks in the same curled conditions. We recognize at once that those beds of sandstone or limestone once crossed right over the Alps from valley to valley, but they have been worn off the mountains while they were sheltered under the soil of the valleys. To take a simple illustration, it is like an old silver-plated statue from the outstanding parts of which the coat of silver has been worn while it remains in the sheltered parts. In this way we know that in the region which we now call Switzerland the crust of the earth has somehow been puckered or crumpled—accordion-pleated, a lady would say— into tremendous folds. In fact, we can calculate that two hundred miles of what was a fairly level plain at one time have been squeezed or cramped into a hundred and twenty miles. The solid rocks, many thousands of feet deep, were pushed into folds, some of which rose to twenty thousand feet or more, as if they were made of rubber. This permitted the molten matter below them to rise underneath the great folds or "pleats" of the crust. It solidified, and the "plating" of sedimentary rock was worn off, leaving the granite; and so we get our Mont Blanc and the other Alps.

Pushing the examination further, we see that the tremendous force which thus crumpled the rocks came from the Mediterranean. In France, Germany, and

Bohemia there are very heavy and solid masses of old rock. It was against these that the crust was pushed. If you put three books on the tablecloth and push the cloth against them, it rises into folds. Something like that happened in the formation of the Alps and other mountains. Something crumpled layers of rock, from three to five miles thick, into folds.

We can go a little further. We can discover a force that is capable of driving the solid crust into such folds. Everybody knows that the water (rain, rivers, and waves) is continually wearing away the land. The rocks are constantly crumbling, and every shower of rain washes away the refuse. The beds of mud and gravel of any large river remind us of this. Stones are broken into pebbles, pebbles are ground into sand, and the sand is heaped on the sloping beds of the seas. It has been estimated that the rivers of the United States convey 783,000,000 tons of material from the land to the ocean every year. The land is so extensive that this only means that the United States, as a whole, loses one inch deep of its surface in 760 years.

But regard it from another point of view. Multiply 783,000,000 tons a year by four or five million years. At the end of that time several thousand *billion* tons would be transferred from one part of the earth's crust to another. Most probably the pace was not so rapid in earlier ages, but it was always rapid enough after an Ice Age (when the land stood high). Anyhow, in time, billions of tons of stuff are worn off



THE MAKING OF THE ALPS

Above, an outline of the Swiss mountain-chains; below, the experiment with a table-cloth

a continent and laid upon the sloping shelf which we call the bottom of the sea (near the shore).

This is a very serious alteration of the equilibrium of the crust. The ocean floor sinks slowly under the load. On the land the lighter crust steadily rises. In the end a very serious strain is set up in the crust. There is a prodigious pressure from the sea towards the land, and it is only relieved by part of the land, next the shore, rising in giant folds as it is pressed against the harder masses of the interior, and permitting the molten matter to rise under the folds. Thus have all the great mountain chains been formed. It is estimated that this force exerts a pressure of 20,000 to 30,000 lbs. per square inch, according to the depth.

The next step is the wearing down again of the new mountains, and it proceeds rapidly while the land is elevated and the water runs freely. But between the two processes is the interval with which we are concerned—an Ice Age. For from a quarter to half a million years—it is generally estimated—the region shudders under its burden of ice and snow. The moving ice then wears down the new land, and thus in time brings about its own disappearance. It reduces the mountains to a level at which glacial conditions no longer occur. The great floods of the melting ice in their turn do a vast amount of scouring. The "eternal hills" vanish once more, and the earth returns—or did in earlier ages—to its warm lowland condition, until another crisis in the crust occurs.

As a general theory, based upon quite obvious facts, this is very interesting and illuminating, but science never pretends to have discovered the final or whole truth about anything in half-a-century. Philosophy is two thousand years old, yet it does not put before us a very large body of accepted truths. As to theology. . . . But we will give it a rest. It is enough to say that no one is more conscious than the man of science of the imperfectness of our knowledge; though, in point of fact, the solid structure of settled scientific knowledge is colossal, and is rising daily. And this in a world in which every other system of ideas is crumbling!

This explanation, then, is sound as far as it goes but it cannot answer every possible question. For instance, I drew attention some years ago to a very curious feature of our five Ice Ages. The intervals between them seem to be about fifty per cent. shorter after each Ice Age. I do not know of any geological writer who has paid attention to this curious feature, yet it is quite plain in every recent geological work—it is not a personal *inference*—and I will again explain it.

The geological scale of the rocks which one sees in manuals is really a chronological scale. It puts the rocks in the order of their appearance in time. But we are very uncertain what was the whole period of time taken to form the crust of the earth, so it is only a *relative* scale. Some think that the story of the earth is a matter of fifty million years; some a

hundred, or several hundred, million years. Schuchert, one of the ablest geological writers of our time, considers that "geological time endured about 800 million years." And lately Baron Rayleigh and the physicists have been insisting that the story of the earth is a matter of at least 1,600 million years!

That is a very delicate and difficult and unsolved problem. For my present purpose this does not matter, because *relative* periods of time will do. The geologist divides past time into Eras, and each of these is sub-divided into Periods. Each represents a certain group of rocks, the thickness of which is fairly well known, so that—allowing for different rates of formation at different times—the geologist roughly knows the length of one Era as compared with another.

There are five of these Eras, corresponding to five levels in our fifty-two miles of rock. Now the modern geologist tells us that, if we represent the whole thickness (the whole of geological time) as 100, the proportion of each Era is as follows:

The Cenozoic Era	5
The Mesozoic Era	12
The Palæozoic Era	28
The Proterozoic Era	15
The Archæozoic Era	40

All the estimates work out at something like this, because the figures really express the thickness of

the known rocks. Well, the last Ice Age was at the end of the Cenozoic Era—"the other day," one might say, on this scale of time. The previous great chill was at the end of the Mesozoic; the one before this at the end of the Palæozoic; the preceding one at or before the beginning of the Palæozoic. So far, for four Ice Ages, it is certain that the interval has been reduced by about fifty per cent. every time. There remains only the first Ice Age, and here estimates are uncertain and conflicting. But it occurred somewhere about the middle of the appallingly long Era (as long as all the others put together) before the Palæozoic.

That is a singular phenomenon. It not only suggests that the earth will be permanently covered with snow and ice in a few million years, because the intervals between Ice Ages will shorten until they disappear but it makes one suspect a machinery which is unknown to us. There is a sort of rhythm about it which excites curiosity.

There is only one group of facts in modern geology which I can conceive as throwing some light on it. It is agreed that the abysses of the ocean are becoming deeper as time goes on. The floor of the seas is sinking, and we may presume that the land is rising. At all events, the land is much higher than it used to be. The facts are still not very well known, and it may be that the explanation is somewhere in this constant need of the mass of the earth to adjust itself to the

changing conditions. It seems to do so, not continuously, but by a mighty spasm of mountain-making at long intervals, and these give us our revolutions of climate or Ice Ages.

But many readers will be disappointed unless they hear something about another theory of mountain-formation which was once very popular, though it seems nowadays in danger of joining "the astro-comical theory of Ice Ages" in the land of lost hypotheses. However, it is by no means dead, much less damned, and it will serve to illustrate another aspect of the question.

We all remember how it used to be explained that mountain chains are wrinkles, marks of old age, on the skin of our planet. An old man's skin becomes too large for his diminishing body, and it grows smaller by "wrinkling." So, it was said, the earth is cooling and contracting, age by age, and thus its skin (crust) becomes too large. It adapts itself to the smaller body of the globe by wrinkling; but the wrinkles go outward, instead of inward, as our skin does.

This, again, is a picturesque and attractive theory, but it is rejected by a large number of modern geologists. The rocky crust or skin of our earth is between fifty and sixty miles thick, and at one time everybody thought that the rest of the globe was molten matter at a very high temperature. We thought that the earth had once been a fiery mass of molten metal,

a little sun, and had merely cooled at the surface. There is now a new theory in geology, that the loose stuff which was brought together to form our globe did *not* engender heat enough to make the whole mass molten; that it was only fiery and molten at the surface. On this view the great mass of the earth is solid and rigid, and cannot shrink to the extent that was once thought.

In spite of the large number of distinguished geologists who follow this (Planetesimal) theory, there is a good deal to be said for the older (Nebular) theory, and it is well to wait. Not only the sun and all the stars, but Jupiter and Saturn, are just as the old theory demands. But we must not go into those matters here. The geologists of the new school do not admit the "wrinkling." At the most they admit that some obscure changes are going on in the atoms of the heavy metals (uranium, radium, etc.) down below, and that these changes may co-operate with the causes we described in the work of forming mountains.

Such, then, is the mechanism which indirectly leads to the Ice Ages. Now we have to consider the effect of the Ice Ages themselves upon life. Whatever obscurities may remain, we are getting a much more satisfactory knowledge of what we may call the machinery of the planet. And upon the action of this purely physical machinery the story of the slow advance of life has depended throughout the ages.

While philosophers and a few mystic-minded men of science have been working out theories of some vital force that sought its way upward—a force far more mysterious and unintelligible than the facts it is invoked to explain—science has been patiently working out the real explanation. If I may use a rather exaggerated illustration, it is as if a race of creatures that had no sense of elevation—that saw everything flat—were watching the course of the Thames or the Hudson acrosss the country, and, wondering why the river followed this particular path, thought that there was some mysterious river-spirit or river-god that directed it. Then a man with normal vision comes along, and he explains that the course of the river is simply directed by the configuration of the ground. That is how science is now explaining the course of the river of life.

Let me repeat that science does not say that it has *explained* the course of the life-river. There are people who accuse science in general, and its popular exponents in particular, of dogmatism. It is a quite false charge. When we have completely mastered the physical conditions of the evolution of life we have still a long way to go. We have then to explain the internal machinery, inside living things, which enables life to adapt itself to the changing external circumstances. This is being done, but more slowly. It is far more difficult. But we have not yet completely studied even the external circumstances which

directed the evolution of life. I am merely giving our knowledge as far as it is settled, and showing how wonderfully illuminating it promises to be.

The first two Ice Ages are the least known. That requires little explanation. We know an Ice Age by the scars it has made on the surface of the planet, and time is apt to remove them. Rocks on which glaciers scratched their signature are worn away. Beds of glacial rubbish are washed away by the sea or a great river. Fortunately, however, these memorials of Ice Ages are sometimes buried under strata which have escaped the war of the element ever since, and the inquisitive geologist of modern times has found them.

But there was no life on land during the first two Ice Ages, and we will dismiss them briefly. As I have explained in *The A B C of Evolution*, the first half, or more, of the drama of evolution was played in the ocean. Life is a product of the water, probably of shallow seas, and in the water it remained until more than half the story of the earth was over. Early Ice Ages would, no doubt, affect even the marine population, though we do not trace this in the scanty early records; but their agency is not important until there is life on land. However, to make complete the story of the Ice Ages themselves, we will see how these early revolutions are known.

Four or five pages back I gave the list of the earth's "Eras." The lowest (and earliest) two, the Pro-

terozoic and Archæozoic, are still sometimes combined as one, the Archæan (or Ancient Age), and we will take them together here. As the figures in my list corresponding to each Era show, this vast age represents more than half the earth's story, although by the close of it life had not risen higher than the level of the worm and the starfish. The rocks of this age are, moreover, overwhelmingly volcanic. They represent tens of millions of years of constant and prodigious outpours of lava through and upon the thin crust. That is what we should expect, precisely because the crust *was* thin.

Somewhere about the middle of this long fiery youth of the earth an Ice Age occurred. We have no traces of the *original* crust of the earth, the first skin of rock to be drawn over its molten body. But there are a few large sections of the face of the earth to-day which have been above water from primordial times, and one of these, which geologists call Canadian, is a very large part of the northeast of North America. The Canadian geologists have found that some of the beds in these formations point indisputably to the rise of vast mountains, followed by an Ice Age. There are great masses of boulder-clay (the scoured dust intermingled with blocks of stone), which have since been converted into rock. The boulders are rounded and scratched in the usual manner, and the quantity of the material points to a really great Ice Age. One bed alone is five hundred feet thick, and stretches

over a thousand miles. Geologists are agreed that this was the earth's first revolution, and that it corresponds with an age of mountain formation.

We will not try to picture this glacial interlude in the fiery drama of the earth's early life. The record is too worn, too faint, for realistic pictures of those dim ages; and there was no land population to feel the selective action of the revolution. It is enough for our general purpose that there was incontestably a great Ice Age; that it is connected with the rise of chains of mountains; and that, as far as we can place it, its chronological position is consistent with the curious law of diminishing intervals to which I have drawn attention.

At the end of this very long Era (taking the Proterozoic and Archæozoic together) there was a second Ice Age. From this point onward, in fact, the end of one geological Era and the beginning of another is precisely dated by a "revolution"—a rise of mountains and great lowering of temperature. Generally speaking, the earth still enjoyed a very warm climate, a perpetual summer, from Pole to Pole. Corals, those pretty and delicate indications of warmth, swarmed in the seas all over the earth. Shell-fish, starfish, sea-lilies, sponges, jelly-fishes, and other lowly types filled the waters. There was still no fish or any dweller on the inhospitable land.

There now occurred an Ice Age which covered widely distant continents with a glacial mantle. On

the theory we are following, ice sheets may be found anywhere during an Ice Age. They will occur wherever new mountains have arisen. We are therefore not surprised to find that there were now ice sheets in Norway, in China, in India, in Australia, and in Africa. The beds of rock containing rounded and scratched boulders are from 600 to 1,500 feet thick in the south of Australia and Tasmania. There is a bed in China 170 feet thick. In Norway the bed rests on sandstone that was clearly scratched and grooved by moving ice.

It is impossible to prove that rocks so distant from each other represent precisely the same age, but it suffices that they all belong, roundly, to the close of the Proterozoic Era and the beginning of the Palæozoic (or, as a geologist would say, the base of the Cambrian Period). Seeing that the climate of the earth had been for millions of years previously, and was for millions of years afterwards, warm and uniform, these great stretches of ice in such different parts of the earth amount to an Ice Age. Cold winds and cold ocean-currents would spread the lower temperature far beyond the actual fields of ice and snow. There must have been a great destruction of marine life. It is not, however, until an Ice Age exerts its terrible influence on a land-population that we get the chief effect which I have ascribed to it, and we will pass to the next.

We have in this case not the same evidence of

mountain-building as in the other cases; though we know that mountains arose at the time at least in America. The geological record of the time is poor, or is imperfectly known. But we shall see this so very plainly in connection with the later Ice Ages that we may assume the cause was the same in Cambrian or Pre-Cambrian times. The earth passed through another of its crises or revolutions. The dragon of cold crept in between two prolonged periods of warmth, and the globe had another foretaste of its ultimate condition.

CHAPTER V

THE MIGHTY PERMIAN REVOLUTION

FROM this point onward the story of the earth is very well known. Our generation is so much accustomed to the gigantic accomplishments of science that one may ask the reader to pause and appreciate what has been done. From some twenty miles deep of compressed stone—indeed, from the comparatively few places where the hand of nature or of man has exposed these rocks to view—geologists have deciphered the story of the life of the earth and its living populations, during some tens of millions of years of past time, in marvellous fullness. The same rocks lay under the feet of the men of every previous civilization. The same quarries and cliffs exposed the secrets of nature to their eyes. Yet until little more than a hundred years ago few had even a dull suspicion of this buried chronicle, and none could read a single line of it as we do to-day.

That story I have told in my earlier works, and I propose here only to add certain details and new discoveries concerning the Ice Ages. The most valuable part of recent geological work is the clearer

perception of what I have already called the general mechanism of the earth, the struggle of the elements. When you read that the rivers bear so many thousand million tons of the land down to the sea every year, and that, if all the "dry land" were thus worn down and conveyed to the bottom of the ocean, the waters would rise 650 feet, you may be tempted to reflect on the misplaced ingenuity which has spent months over these stupendous calculations. But it is all part of the explanation of that drama of terrestrial life which, since the discovery of evolution, has attracted us more than ever.

The next Ice Age we have to consider, the Permian Revolution, came after the age of the Coal Forests, and we will take these as a fixed and familiar point from which we may work. Everybody knows the meaning of our coal-beds. During one or two million years the earth bore forests of such denseness and continuity that the rotted wood has given us the immense masses of carbon in our coal seams. I will assume here that the reader knows that coal-beds occur in every continent, from the Arctic to the Antarctic, which shows that at least semi-tropical forests then flourished all over the earth; and that the Coal Forest implies low-lying, sodden land, with a hot steamy temperature and vast swamps. It was "the age of amphibia" in the record of animal life.

We must bear in mind also that the forests had not suddenly grown thick during the Carboniferous

Period. The vegetation had been growing steadily denser ever since it had invaded the land. The "sea-weeds" became ferns and mosses, and these, finding ideal conditions for their growth, became larger individually, and denser collectively, until they ended in the rich, rank forests of our coal-beds. During many millions of years the earth had enjoyed a great warmth from Pole to Pole. There were periods and places of rise of the land, with dry and cool climate; but what I have given is the general aspect of the earth.

It was the interval between two Ice Ages, the Palæozoic Era, lying between (if the reader will turn back for a moment to the list on p. 63) the revolution which closed the Proterozoic Era and the revolution which opened the Mesozoic Era. And from what we have already seen we understand this. The Ice Age had been due to the rise of the land. But a rise of the land always brings about its own destruction. The rain falls more freely and heavily, as the moisture is chilled and condensed by the hill-tops. The streams and rivers run more swiftly, as the land slopes more steeply towards the sea. The frost and moving ice break up and scour away the mountains. When the ice sheets melt, the vast streams of water are very destructive.

So the earth returns in a comparatively short time to its lowland condition, with a warm climate. The wearing of the land will now be much slower. Sediment will accumulate much more sluggishly on

the floor of the ocean. In this respect the war of land and water relaxes very considerably, and the critical reaction, the pressure against the land which causes new mountains, is long delayed. But there is another thing to be considered. The level of the water has meantime risen, on account of the thousands of millions of tons of worn land that have drifted into it—just as surely as the water will rise in a pail if you put into it a handful of sand and pebbles. The oceans overflow the low-lying continents, creating great swamps and lakes, accentuating the warm, moist conditions.

American geologists calculate that their continent has been thus flooded fifteen times since the Ice Age with which I closed the last chapter—often to the extent of millions of square miles, and chiefly during the Era we are now reviewing. Nearly a dozen times during that Era the waters encroached upon the land until they covered sometimes from thirty to forty per cent. of North America.

These changes are part of the external machinery of evolution, part of the great process which we call natural selection. When the sea spread far over the land there was an immense increase of marine life, as will be understood. When the land rose again to some extent and poured off the waters, all this new marine population was exposed to material changes of conditions and a fiercer struggle for existence. All such changes are very slow, we must remember, and

the animals and plants, or some of them, have time to be adapted to new conditions. This means that they evolve new organs. They pass into different species. It was during one of these temporary rises of the land—a very extensive rise, but not acute enough to cause anything like an Ice Age—that branches of the fish world left the water, and began the story of the quadrupeds. That interesting and important chapter, the struggle for air-breathing apparatus, I have told elsewhere.

The next step to the fish is the amphibian, and the swampy earth of the Carboniferous Period suited this type. The land, or land-and-water world of those days, swarmed with amphibians, sometimes five or six feet long. But a new revolution was approaching. Four times during this Palæozoic Era there had been a considerable rise of land in America, though it did not rise high enough to cause a revolution in climate. The masses of sediment were steadily accumulating along the shores of every continent, and the time of reaction, of thrust back towards the land, had arrived.

In the case of this Ice Age one of the subsidiary causes also was very important. Whatever may have been the primitive condition of the earth's atmosphere, it is certain that it was heavily loaded with carbon dioxide during the Era we have just reviewed. The Coal Forests extracted a vast amount of this carbon. The carbon in our coal seams is two hundred times

the entire quantity there is in the atmosphere to-day; and the very thick beds of limestone associated with them mean (as limestone is a compound of carbon and lime) further enormous quantities drawn from the atmosphere. The air must have been extraordinarily thinned by the end of the Coal Forest period. When the land rose also, forming great ranges of mountains, the dense moisture in the air began to be precipitated. The conditions of an Ice Age were given.

This Ice Age, which we call the Permian Revolution because it occurred at the beginning of what is called the Permian Period, was very intense, prolonged, and widespread in its influence. Its main theatre was, as I said, the land which then linked India, Australia, and South Africa. This was an ancient continent (known in science as Gondwana Land) of which we have the clearest evidence. Probably India was then not united to the rest of Asia—the mountain mass of the Himalaya rose only millions of years afterwards—but was the northern tip of this lost continent. From India the land stretched across what is now the Indian Ocean, and included the greater part of Africa and Australia. Indeed, part of it stretched across the Pacific to South America, and part to Antarctica.

As we find the chief traces of the Permian Ice Age in India, Australia (mainly Queensland, South Australia, Victoria, and Tasmania), and South Africa —the fringes of this lost continent—we take it that

Gondwana Land was the leading ice-field. The memorials of it are such as I have already described. In Central India and down into the tropics we have mighty beds of the kind of glacial rubbish, mixed with boulders, which I described, and the rocky surface below this stuff is grooved and polished by heavy moving ice. Other beds are now raised (by a later elevation) high up on the Himalayas and in Afghanistan.

In Australia we have the same beds in great thickness. I told on an earlier page of having seen these memorials of an Ice Age in the Werribee Gorge in Victoria. In this district the evidence is particularly interesting. It shows that the Ice Age consisted of a succession of cold periods with warmer intervals. There are even thin seams of coal and marine beds between glacial deposits, showing that the climate became warm again, and the sea overran the land. It will be remembered that I suggested a picture of the land, during an Ice Age, sinking to a lower level under its colossal burden of ice, then rising again when the ice melted, and receiving a new burden. These "inter-glacial periods" are, however, not yet absolutely settled in science.

In Africa we have the same indications, and in such abundance that we need not fear to speak of a great Ice Age. There are glacial beds 1,300 feet deep in Natal, and very thick beds in Cape Colony. In fact, the ice-sheet practically covered the area which we

called British South Africa in 1914. And the vegetation is so similar to that of contemporary Australia and India that we safely assume they were parts of one continent. We have the same hardy types of ferns and the same glacial indications in Argentina and Brazil, the western limit of this lost continent.

But in many other parts of the earth also there were ice-caps. Neither of the astronomical speculations we noticed in the least fits the facts of this very well-known Ice Age. There was nothing like polar caps. Apart from the ice that stretched from North India to Cape Colony and Tasmania, there was the ice in Brazil. Then there was so much ice in eastern North America that American geologists prefer to call this Ice Age the "Appalachian Revolution"; and there are further glacial indications of this date in England, Germany, and Bohemia.

Of the cause in this case, apart from the great absorption of carbon, we can have very little doubt. It was one of the great ages of mountain-formation. A chain (the Palæozoic Alps) stretched from Ireland, through Wales and the south of England, to France. Another chain (the Variscian Alps) stretched from France to Bohemia. There were other chains in Armenia, India, Malaysia, Australia, Africa, and America. In North America the western or Pacific coast spluttered with volcanoes, while the eastern fringe rose in a chain of mountains (the Appalachian mountains, from about New York to Georgia), which

are estimated to have reached a height of 20,000 feet, or far higher than the Swiss Alps are to-day. The ground-up remains of the range now lie, 40,000 feet thick, in a deep trough alongside the site of the old mountains.

It was a fresh crisis in the physical fortunes of the planet. Whatever share shrinking, or atomic changes under the crust, may have had, the ten million years or more of wearing away of the land and piling material on the ocean-floor explain a good deal. The ocean-basins may have sunk deeper, thus permitting masses of water to drain off the flooded continents. There was, in sum, an immense gain of the land upon the water, and a considerable rise upward of parts of the continents. From the picture we have drawn of the earth previously to this stage, it will be understood that there was a colossal amount of moisture to condense into snow and ice. This withdrawal of moisture, coupled with the extraordinary withdrawal of carbon that had proceeded for over a million years, greatly thinned the atmosphere, and allowed the heat to escape. There was more dry land than there had ever yet been in the story of our planet, and there was a thinner air to "blanket" it. It was like passing from the thick warm atmosphere of Geneva to the summit of one of the Alps beyond.

I have so fully described in earlier works the effect upon life of this revolution in climate that a short summary will suffice here. But before I do so, let

me make an observation that may help to relieve the perplexity of many readers. Evolutionary literature is in our time so full of flat contradictions that the casual reader is puzzled, if not pained. He reads that Darwinism and natural selection are now unimportant, if not superseded. He learns that "environment," to which we once attributed so much, is now a very subsidiary matter. He must even feel sometimes that environment is negligible, and that the mechanism of heredity is what matters overwhelmingly in evolution.

All these statements are grossly one-sided. Recent science has made a great advance in the study of the mechanism of heredity, and some of those who are engaged in this study lose their sense of proportion. Environment alone could not explain evolution unless it directly altered the features of living things, and they transmitted these features to their offspring. If, for instance, cold itself provoked a coat of fur or feathers on an animal, and this "acquired modification" were handed on to the next generation, we should have an explanation of the change of species. That is—properly drawn out and spread over a great period—Lamarck's theory; but no one now admits it in this form, and few admit either of the two propositions I have stated.

Darwin's idea was quite different. He assumed that some *internal* cause brought about differences between young and their parents, or "variations."

He repeats constantly that he takes these variations for granted; and I have quoted him saying that he believes *external* causes have very little to do with variation. But science in his time knew very little about the internal or embryonic cause, and Darwin chiefly occupied himself with what followed. Environment "selected" those variations which were favourable to the possessor. On a white background, for instance, the chances of survival are against a *dark* animal; on a dark background they are against a *light* animal. That is one feature out of myriads. So, if the young differ constantly from their parents, the environment often has a good deal to say to the variations.

Since that time we have learned much about the embryonic machinery, although we are very far from having mastered it. Unfortunately, some of the students of heredity use language which seems to the general public to mean that all the older study of environment was useless. On the contrary, it has not lost a single particle of its value. Internal forces alone can no more explain evolution than external forces could. If we supposed that there was some internal force which pressed life on from the level of the fish to that of the reptile, then to that of the bird or mammal, we should be taking refuge in a mysticism that really explains nothing and is not science. If we supposed that this internal force caused the fish to develop into a reptile (through the amphibian

stage) without regard to the fact that meantime the land became higher and drier—that the same mystic force converted the reptile into a bird without regard to the Ice Age which now occurred—we should be guilty of an outrage on common sense.

Both factors, internal and external, were essential to the evolution of life. We want the internal power of growth and the external pruning and shaping forces. Without the rise of the land in the Carboniferous Period there would have been no reptile. If the embryonic forces had produced one, the external conditions of the Coal Forest Age would have destroyed it. Without the further rise of the land to the extent of causing an Ice Age there would have been no bird or mammal. If they had arisen, from purely internal causes, they would not have found the conditions of survival. The physical story of the earth has guided and shaped the course of the life-story just as the land-conditions direct the course of a river. That is Darwinism, or the origin of new species by selection. Theories of heredity are supplementary to this, and we are as yet much less confident about them.

The Permian Revolution itself is one of the clearest illustrations of this. The reptile appears just before it sets in. That is to say, the land is beginning to rise and, as the waters are drained, amphibian life becomes less easy or even, in places, impossible. In some such region the amphibian loses its gills

and becomes a reptile. The amphibians in nature to-day show how easily this would occur. The frog loses its gills, but keeps mainly to the water; but in a waterless region it is a pure land-animal—sometimes a tree-animal—and almost has no tadpole stage. There are, on the other hand, amphibians (the axolotls of Mexico) which retain the gills all their life, and never live on land, because their water-conditions are excellent We can even control the development of amphibians by giving them either a land or a water environment, as we wish. They show the most perfect interplay of internal forces and environment.

But the reptile, if it requires dry land for its original development, requires also warmth. It is cold-blooded and cold-coated, and it does not warm its eggs. Hence, when the land continued to rise at the close of the Coal Forest Period, the development of the reptiles was checked. As a rule, when a higher type of life is evolved it enjoys a period of great prosperity. Its individuals run to a great size—there were once oysters a foot in diameter and sharks thirty feet long—and the whole family is rich in numbers and variety. But the reptile family was checked by the increasing cold, and its great expansion was postponed until the Ice Age was over. To try to disconnect these things from environment is obviously foolish.

The Permian Ice Age may have lasted a quarter of

a million years. If we bear in mind the extraordinary area it covered, and remember that cold winds and cold currents would go far beyond the ice-fields—that, in fact, there was probably a winter season over great stretches of country that were not glaciated—we see that the greater part of the earth was subjected to a heavy trial. There had been, remember, no ice, no snow, and no winter anywhere on the earth for something over ten million years. Every branch of the living world was adapted to warmth. There were, no doubt, broad regions which remained quite warm, but over a very great part of the earth the living population was put to the test of natural selection in its most terrible form.

For the majority it was an unmitigated catastrophe. How do we know? Geologists compare the species of animals and plants which they find fossilized in the later Coal measures, before the revolution, with the species they find in the rocks at the close of the Ice Age. Thirty-nine out of every forty species have disappeared. Many new species have appeared, of course; some of the old species have passed into higher forms. But even these changes, under the influence of an Ice Age, involve an immense carnage of individuals. It was a period of the most terrible destruction of life. Had there been reptile philosophers and theologians, they would have pronounced it "the crack of doom." They would have lamented that their race, the flower of creation (as they then

were), had only just reached supremacy in time to witness the end of the world.

But the earth had still tens of millions of years to offer to its living inhabitants. The ice slowly reached its culminating point, and then slowly receded. If there were inter-glacial periods, warmer (or less cold) periods between successive spreads of the ice-caps, we can only think that they would add to the severity of the trial. Animals would spread out from the warm regions, which would obviously become densely populated, and they would be fairly established in the new lands when the stress of the glacial conditions would fall upon them again.

I must, however, refer the reader to my *A B C of Evolution* for an account of the way in which the cold conditions would act. Here it is merely necessary to emphasize the *slowness* of these changes, which the inexpert find it difficult to grasp. Take a glaciated region like Australia. Now we are less disposed than ever in science to give chronological figures; not that the old figures were excessive, but because they are probably far short of the truth, and they are in any case very uncertain. But no one would imagine that the change from Coal Forest conditions to glacial conditions in Australia took less than ten thousand years. This is, of course, not a suggestion of anything like the actual period. It is a figure that we can safely say is not large enough; though it is longer than the whole stretch of civilization.

If you spread an average fall of temperature of, say, twenty degrees over ten thousand years, you realize what a great opportunity is given to the adaptive powers of organisms. A thousand generations of reptiles, ten thousand generations of ferns, would appear in that time. Every variation in the direction of protection of the animal and its eggs from cold would be favoured. There was time enough for the very large changes which are involved in the evolution of reptiles into birds and mammals; and, as I have described in detail elsewhere, the earliest birds and mammals which were obviously transformed reptiles, appeared at the close of the Ice Age. The plant world was in large part similarly transformed. The primitive ferns and club mosses of the Coal Forests disappeared. The pine and the yew, the cycad and other new types, spread over the earth.

By the time the Ice Age was over life had been lifted to a distinctly higher level. It is not too much to say that more progress—more advance towards the higher types of life—had been made during that quarter of a million years (to use a rough estimate of the entire period) than during several million years that had gone before it. There had been a revolution. But the word "revolution" must not mislead us. Measured by our familiar standards of time, it was still a period of *very slow evolution*. The point is that evolution is by no means uniformly slow. During

these revolutionary periods its pace increases considerably.

And the *increase*—the swifter advance towards the higher level—is due to external, not internal, causes. We have no reason to suppose that the changed environment provokes the embryonic machinery to act, to produce variations, more rapidly; and, even if we had, this would be action of the environment. On the other hand, to suggest that the internal factors happened to produce variations more abundantly during these externally revolutionary periods would be mysticism with a vengeance. There was once a religious philosopher who, despairing of finding any explanation of the influence of spirit on matter, and vice versa, said that the two sets of causes, spiritual and material, just happened to coincide. When you felt angry, your body was so nicely "wound up," as it were, to keep time with the spirit that *it* showed anger when *you* felt anger; but the mind did not influence the body. We can scarcely admit this sort of thing in science. The internal and external factors work intimately together. Natural selection is of fundamental and universal importance.

CHAPTER VI

THE COLD THAT SLEW THE DRAGONS

THE reader must not suppose that in the rocks which represent the Permian Revolution we find reptiles gradually evolving in the direction of the bird and the mammal. Not only do we not find these interesting stages preserved, but we have very few traces indeed of birds or mammals during several million years after the Ice Age; and the first traces we have are much later than the Ice Age. The bodies of land-animals are rarely preserved. They usually lie on the soil until decay and bacteria have disposed of them. If one reflects how many hundreds of thousands of birds must die in England every year, yet how few bodies of birds one sees, this fact will hardly need further explanation. The scavenging department of nature is very efficient.

But the first birds and mammals which we do find are of such a character that it is impossible to doubt their reptilian ancestry, as I have elsewhere explained. For a very different reason it is equally impossible to doubt their connection with the Ice Age. The whole transformation of a reptile into a bird or mammal is

an adaptation to cold. It means, especially, three things—warm blood, a warm coat, and warmth for the eggs or young. One might, of course, suggest that they were evolved in some period of cold that was later than the Ice Age. As a matter of fact, there was a restricted but severe chill in the geological period immediately following the Permian. It is as if, in some part of the earth, the crust failed to rise at the appointed time and the formation of a certain mountainous region, with the inevitable chill, was delayed. Obviously, however, the prolonged Permian Ice Age is the most natural period in which to place the main part of the evolution of the mammal and the bird.

The Ice Age slowly ended. The earth returned to its universal warmth. A new "golden age" opened; if warmth and abundance of food mean a golden age. But pleasant ages of that description are reactionary ages. Again, the social student need not take alarm, for we are speaking here always of the conditions of life of unintelligent animals. For those the spur of adversity is necessary.

Golden ages have their own machinery of evolution. Plants and animals multiply so prodigiously that they come at last to a keen competition with each other. Picture the condition at the close of the last Ice Age. At least four million square miles of land were restored to what we may broadly call purposes of pasture. They were again covered with a rich vegetation, for

there was still no winter suspension of life for the plants. Moreover, the temperate zone round the glaciated region returned to semi-tropical conditions. It is important always to bear in mind this great fringe of territory, with greatly reduced temperature and vegetation, round the actual region of ice and snow. It enormously extends the influence of the Ice Age. With the return of the sun, the whole of these vast regions would once more be clothed with vegetation, and the animals, spreading out from the restricted zones in which they had sheltered, would grow to a great size individually and to very large numbers collectively. They would breed astonishingly. Over-population, rivalry, and carnivorism would follow.

But, in spite of its perennial interest, I must abstain entirely from telling again the story of the giant reptiles which now covered the earth. Several million years passed, during which progress consisted almost entirely in the growth of arms and armour. It was the progress of war time—a pitiful waste of resources and time from any higher point of view. It is generally called "the Age of Reptiles." One might almost call it "the age of teeth." Sharks developed fearsome triangular teeth five or six inches long. Flying reptiles got more than two hundred ugly fangs in their jaws. Evolution, certainly, but . . . We almost prefer to contemplate an Ice Age.

At all events, that is what we are going to do here.

We are going to skip this long time of carnage and stupid bulk and come to the next revolution in climate. The story of the earth which underlies and directs the story of life is just the same as we have seen previously. The mountains which caused the Ice Age were worn down. The earth returned generally to a lowland condition, to a predominance of the water over the land. One has to remember that the earth as we know it to-day has higher land and more variety of scenery than it had in the past. It is only about thirty thousand years since the end of a very great Ice Age. The mountains are still lofty, and the ocean abysses are deeper than ever. During the Age of Reptiles the land was generally very low and swampy, the climate very warm and moist, the area of water enormous. Most of Europe was under water, and a marshy continent stretched from Europe to North America, which also was largely under water. The giant reptiles probably lived mainly in water, like hippopotami; many of them were exclusively aquatic animals, as the whale is to-day.

In a word, the key to the puzzling story of life is, as usual, the physical story of our globe. The man who starts on hearing such an explanation, and calls it "Materialistic," is like a horse jibbing at a flying newspaper on a windy day. Materialism may or may not prove to be the final truth, but in the meantime the unravelling of these material factors or conditions of progress is decidedly illuminating. We leave open

the question of the internal machinery of progress until science is much better acquainted with it. But we do see that any man who tries to tell us that a "vital principle" was working out the course of evolution on a definite plan is playing with words. At every step this course of evolution is conditioned by changes in the physical world which cannot reasonably be connected with any sort of plan.

This was plain enough as regards the first appearance of the bird and the mammal. One would almost say that it was *dictated* by the physical changes in the earth itself—understanding, of course, that the response of life would have been quite impossible without some remarkable machinery in the animal which could bring about the new adaptations. It is just as plain in regard to the next great stride in evolution: the extinction of the great reptiles and the triumph of the mammals and the birds.

According to the table which we gave on a previous page, the Age of Reptiles was, in duration, about one-eighth of the entire story of the earth. What that means in positive figures we cannot yet say; estimates range from ten to a hundred or two hundred million years. It is, as I said, the radiologists who give us the highest figures, and one does not like to accept them until the evidence is more extensive and unquestioned than it is; but even the geologist, Professor Schuchert, would make this age (the Mesozoic Era) about a hundred million years.

It is another vivid reminder how the progress of life waits upon the physical accidents of the earth. The highest types of life, the mammal and bird, were born about the beginning of the period. They had no advantage, however, when the ice disappeared and the earth became warm again. They remained half-formed, as it were. The bird remained half a reptile—with long tail, and with toes on the end of its front limbs—for millions of years; and it still had teeth in its jaws near the close of this long period. The mammal remained at the level of the Australian Platypus (which lays eggs) and the kangaroo (a primitive mammal) right to the close of the period. Birds and mammals were comparatively scarce, and they did not multiply into a great variety of types. To them the "golden age" of the reptile was a period of great adversity. They had in them the germs of the highest types of life, yet they made infinitesimally slow progress during these tens of millions of years. The whole higher promise of life awaited a change of climate.

It came slowly and gradually in the last part of the Era. Most of Europe south of Scandinavia was under water, though large islands, surrounded by beautiful coral beds, rose above the warm ocean. An open sea spread from the south of England to the Indian Ocean. The chalk beds which extend over this area mainly consist of remains of microscopic animals and plants which lived in the shallows of

this sea, and covered themselves with coats of lime. They enable us to trace the extent of the sea. They are, to the general public, the most striking beds of the time, and, although geologists do not now regard them as the most important, they still give their name to the period. It is called the Cretaceous (or Chalk) Period.

This was the period of the next revolution, and, as I have said that we must hesitate to call it an Ice Age, it is necessary to say very precisely what happened. We know that there was a great rise of the land. After what we have already seen, we might infer this from the profound changes in the kingdom of life, which now experienced one of its greatest revolutions. But in order to avoid all appearance of arguing in a vicious circle, we will take the rise of the land as it is determined by geologists, quite apart from the fossils entombed in the rocks. The method requires little explanation. Where, as in so many parts of England, the chalk is at the surface, we know not only that it has been lifted up from the bottom of a shallow sea,[1]

[1] It used to be thought that the shells or skeletons of minute animals (Foraminifers) and plants (Algæ), which chiefly compose the chalk, formed at one time an ooze at the bottom of the *deep* sea. This is not now considered to be the case. The explanation of the seams of flints which occur so often in the chalk may interest many. The chalk-mud or ooze at the bottom of the shallow sea would naturally contain abundant remains of sponges. It is thought that, after the chalk had been raised and converted into dry land, the rain-water percolated into it and dissolved the silica in the sponges, which was then deposited or concentrated in the form of flint.

where the skeletons of the chalk-animalcules gathered, but that it has remained above sea-level ever since (unless we can trace beds which have been washed off it). Hence the mud must have been raised up, by an upheaval of the crust generally, at the close of the Chalk Period itself; otherwise later deposits would lie upon it. In the same way we can tell that a great part of Europe and America rose at the close of the Chalk Period. No later deposits have been laid upon it, as would inevitably be the case if it had remained longer under water.

We can, in fact, learn that there was a very considerable disturbance of the earth's crust in the later part of the Chalk Period. There was an immense amount of volcanic activity. The west coast of America, in Chile and from Mexico to Canada, flamed with volcanoes. In India there was one of the greatest outpours of lava that can be traced in the geological chronicle since what I called the fiery youth of our globe. The hardened lava spreads over 200,000 square miles, and is in some places a mile in thickness. So much may be quoted by those who think that a veil of fine volcanic ash in the upper atmosphere may be a cause of glaciation, but it is very difficult to imagine this ash remaining during anything like the long period of an Ice Age.

In other places we have the plainest indications that the land was rising. In the preceding chapter we saw that a range of mountains, the Appalachian

(from New York to Georgia) rose in the eastern part of the United States, and was worn down again after the close of the Ice Age. The material, which had been laid in beds or strata under the sea, was now again crumpled into a lofty range of mountains. In the west of America, where the terrific volcanoes evinced a great disturbance of the crust, mountain-building was very conspicuous. It was the time of the birth of the vast mountain-system which spreads from Cape Horn to Alaska. The Cordilleras, the Andes, the Antilles, and the Rocky Mountains lumbered slowly upward, though they did not reach the height which we shall find them reaching on the eve of the next Ice Age. One range, the Laramide Mountains (in the region of Wyoming and Colorado), is believed to have reached a height of 20,000 feet. Fifty miles of the earth's crust were here crushed and pleated into one-half that distance. The North American continent, generally, rose from the waters which had long covered it. In fact, American geologists speak of this as "the Laramide Revolution."

There was a similar, though less extensive, rise of the land in Europe and Asia. The Alps and the Pyrenees began to rise. The waters of the warm coral sea, with giant sharks and reptiles, that had for millions of years covered the greater part of Europe, were to a large extent shaken off, or drained into the ocean depths. Switzerland, until then at the bottom of the sea, began to contract into the

huge folds which we know as the Alps. The Himalayas began to rise at the same time. The Chalk ocean which had spread from England to India, and southwards deep into Africa, was broken up by rising stretches of ground into a series of seas or lakes.

In other words, nearly all the principal mountain chains which we know to-day—or the worn stumps of which we know—were born at this period. But in nearly every case they failed to reach their full height. In the earlier (Permian) revolution of climate we had what we may call a complete operation of mountain-building. In this case we have an incomplete operation. The rise of the land was very massive and extensive, but generally not so high as it had been in the Permian, and would be in the later, revolution. The formation of our great ranges of mountains was to be spread over millions of years. There was a mighty beginning in the later stages of the Cretaceous Period. Then we shall see there would be periodic advances during the warm period that followed, and finally a vast elevation that culminates in an intense Ice Age.

This helps to reconcile us to the fact that the present revolution in geology and in climate was not accompanied or followed by what we can definitely call an Ice Age. There was, as far as we have yet discovered, no immense field of ice and snow covering millions of square miles. It is not at all true that, as one sometimes reads, there was *no* "glaciation."

European geologists found long ago that there were glacial beds in the region from Vienna to Bavaria, and that the boulders in these beds came, not from the Alps, but from a range of mountains in the neighbourhood of Bohemia. There was obviously a remarkable change in the climate of Europe. Where blue coral seas had hitherto smiled in the sun, there were now broad and deep rivers of ice pouring sluggishly upon the plains.

Only in recent years (1913) similar glaciation has been discovered in America. Beds from eighty to a hundred feet thick were traced in Colorado, and the boulders must have come from mountains forty miles away. Professor Schuchert says:

> "It is to be expected that other areas of these tills will be found, in which event it will appear that the Laramide Mountains were then widely covered by Alpine and Piedmont [broad-fronted] glaciers."

This snow-covered range, pouring large glaciers forty miles over the land (and therefore immensely larger than any in Switzerland to-day) must have made an impression on the climate of North America.

It will now be clear what I meant when I ventured to call the period an Ice Age, but one not in the same category with the other Ice Ages. It was rather a period of chill, a very extensive and deadly chill in Europe and North America. Again we may note

that there was nothing in the least like polar caps—nothing to lend the feeblest countenance to the old astronomical theory—and that the ice occurred simply where there were the greatest elevations of the land. The whole of the facts are, therefore, consistent with the theory we have accepted. By the very general alteration of the elevation of the land the atmosphere was put into more energetic circulation, and its high proportion of moisture was reduced by falls of snow and rain. But the new mountains do not seem to have been high enough, as a rule, or the moisture not great enough where the land was high, to form a great ice-cap anywhere on the earth. A cold period, but not strictly a glacial period, followed.

And this was the chill that slew the dragons of the earlier Era. There has been a good deal of speculation as to the identity of the St. George that did this remarkable amount of dragon-slaying, but every agency that has ever been suggested, except cold, is ludicrously inadequate. Early mammals of the type of the innocent duckmole and the almost equally inoffensive kangaroo had no chance against twenty-ton reptiles, armour-plated from snout to tail, or flying reptiles with two hundred ugly teeth; to say nothing of the fact that it is not clear that carnivorous mammals (except insect-eaters) had yet appeared. Speculations about the disappearance of the race of giant reptiles from internal decay are just as unsatisfactory, and just as superfluous.

The physical change of the earth itself is the obvious explanation. There had been very rich and luscious vegetation on the warm, low-lying, watery earth of the earlier Era. The monstrous size of the reptiles themselves is proof enough of that. When the earth, in Europe and America, was raised and drained over so enormous an area, there would be a proportionate thinning of the vegetation. But the cold had a more direct effect. The climate of Europe and North America became less and less suitable for reptiles. In particular, the mother reptiles provide no warmth for their eggs, and the cooling earth would no longer suffice to hatch the eggs. The turn of the bird and the mammal, which were especially evolved to meet cold conditions, had come at last. The river of life entered upon a new stretch; and nowhere in its whole course is it plainer that the material circumstances guided the flow.

Apart from this negative evidence—the general extinction of the reptiles, at least the larger reptiles, in Europe and North America—we have abundance of positive evidence of cooling climate. The modern type of tree, the hard-wood flowering tree (oak, beech, etc.), began to spread over the northern hemisphere. The plant world, as well as the animal world, entered upon its modern development.

The remains of plants which we find in the lowest and earliest beds of the Chalk series show that the earth still possessed its old type of climate. We

should certainly not say that it was just as warm at the Poles as in other latitudes, but it was so warm there—had been all the time except during the Ice Ages—that the same vegetation grew at the Poles as in other regions. There is no difference between the trees of the coal-seams in the Arctic and Antarctic Circles and the trees of the Australian or English Coal Forests. Early in the Chalk Period, however, we begin to find a difference. We can see that there are zones of climate; that the vegetation farther north differs from the southern vegetation. And the main difference is that farther north there is a spread of the flowering trees which shed their leaves annually.

How these were evolved, and what the precise meaning of this annual fall of the leaves is, we cannot repeat here. It is enough to say that they mean a cold season of the year, a winter season. No such season can be traced earlier in the story of the earth. Now we know unmistakably that it has set in, for we find the fossil imprints of leaves of such trees, and also tree trunks with annual rings of growth. Fossil trees, three feet thick, have been found in the Arctic Circle with no less than two hundred and ten rings, indicating so many winter seasons. They belong to this period. At the same time the corals, which are very sensitive to cold, disappeared from the polar regions, and even from North Europe. We have no reason to suppose that corals are more sensitive to

cold to-day than they were formerly, yet we now have them almost confined to the tropics. Their retreat from higher latitudes at the time we are discussing tells us what the climate of the earth had been up to that time, and what a change was taking place in the Chalk Period, as the masses of the land slowly rose out of the deep.

Thus our Cretaceous Ice Age, although so much less acute than the others, was not less important in its influence upon the evolution of life. A veritable revolution occurred. At the time, no doubt, it would have seemed, if there had been observers, a painfully slow evolution. The progress would be no more evident than it is to-day. But to us who find the life-story condensed into a few thousand feet of rocks the change seems enormous. The face of the Northern Hemisphere was transformed. The older types were annihilated on a colossal scale. Birds and mammals replaced the reptiles; modern trees and shrubs replaced the cycads and other ancient forms of vegetation; grasses began, for the first time, to cover the plains.

The transformation seems to have begun in America. With the great rise of land which we described, whole regions which had lain under water were drained and dried. Coarse sedges, the forerunners of the familiar grass, developed in the beds of the former lakes or inland seas. On the rising and cooler ground the old types of trees could not prosper, and such trees

as the willow, elm, oak, and maple overran the landscape. In the course of the Cretaceous Period itself there also appeared the magnolia, laurel, holly, fig, plane, birch, beech, walnut, hazelnut, and many others. From America they spread to Greenland, and some time afterwards they appeared in Portugal and pushed over Europe. From Greenland to Portugal seems a long jump for the plant-world, but there still existed across the North Atlantic a connection between America and Europe. We may suppose that this "lost continent" was elevated in the Chalk Period—we may even suspect that it may have in it some of the missing evidence of glaciation—and the new forests and grasses slowly travelled across it to Europe. Such travels are easily accommodated in the long periods of geological time.

Just as I write this page I receive press-cuttings that tell how a distinguished English professor has been saying—to the great joy of narrow-minded folk—that the Darwinian era is over and discredited, and that we face the problem of the causes of evolution almost as blankly as ever. Such language is unfortunate and misleading. The reader will judge for himself whether the material of these chapters does or does not throw light upon the evolution of life, and whether the explanation is not on the main lines of Darwin's teaching. The professor in question is so exclusively devoted to the *internal* causes of evolution—the causes of variation—which baffle him, that he

ignores what has been done in the study of environment; as if the evolution of life had proceeded on its own lines in sublime indifference to these mighty, significant, and most illuminating physical changes in its environment! However eager we may be to solve the dark problem of heredity, or defend any particular view of it, we need not slight the brilliant work that has been done in making clear the selective action of the environment.

CHAPTER VII

THE ICE AGE THAT MADE MAN

UNTIL the period of great chill which we described in the last chapter, the entire earth had been warm all the year round. Periodically, at intervals of millions of years, a large part of the surface was glaciated, and the climate generally affected; but after each of these temporary intrusions of cold the earth had returned to a warm climate. There were no arctic circles, no temperate zones, no cold winters. At the end of the Cretaceous Period we find a marked change. The earth was cooling at the Poles, and in the temperate zone there was the annual chill which we call winter.

Yet the earth returned to a degree of warmth which we enjoy no longer to-day. As I stated in an earlier chapter, we find under the snows of Spitzbergen the frozen remains of flowering plants that would not now prosper even in England. We find England and France clothed with a vegetation which we should not at present expect north of Morocco. We find, long afterwards, that the elephant and hippopotamus were as much at home on the plains or in the streams of this

part of Europe as they now are in Africa. Indeed, it is the opinion of many high authorities that the most important family of animals on the earth, the Primates (monkeys, apes, and man), developed within the Polar Circle, and descended south only as the earth progressively cooled.

All this I have described in the earlier manual. I want only to refresh the reader's memory in order to throw into strong relief the effect upon man of the next Ice Age. Cold, as such, is not a beneficent agency. Adverse circumstances may stimulate a few to rise above them, but for the majority they mean an absorption in the problems of the hour which leaves no time or inclination to think of progress. The earliest civilizations were not born on the fringe of the ice-sheet, but far south of its greatest extension, and in the most fertile and comfortable valleys which the region afforded.

It is chiefly the supervening of the cold upon a warm climate which stimulates evolution. We must, of course, not understand that too narrowly. It may have been—probably was—in the *later* stages of the Permian Ice Age that the bird and mammal were evolved. The advance of the cold, the conversion of fruitful into bleak and inhospitable territory, would at first tend simply to press the animals backward into the regions which remained warm. These would in time be over-populated, and the intense struggle for life would drive some back into the temperate

fringe, where there would be less competitors. I have suggested that this was the way in which certain families of reptiles were gradually adapted to the cold, and became birds and mammals. But this comes, in the end, to the same thing. It was the supervening of an Ice Age upon a uniformly warm earth which caused the evolution.

I am going now to suggest that, in the same way, the glaciation of a Europe which had previously been warm throws a remarkable light upon the making of man. It will be noticed that I speak only of "suggesting" this. It is by no means the settled teaching of science. The *facts* which I give as the basis of the suggestion are, of course, undisputed, but science is only now feeling its way towards a general conception of the early history of man, and there is still a great deal that is obscure and unsettled. The reader will judge if this connection of man's advance with the last great Ice Age does not greatly illumine the whole story.

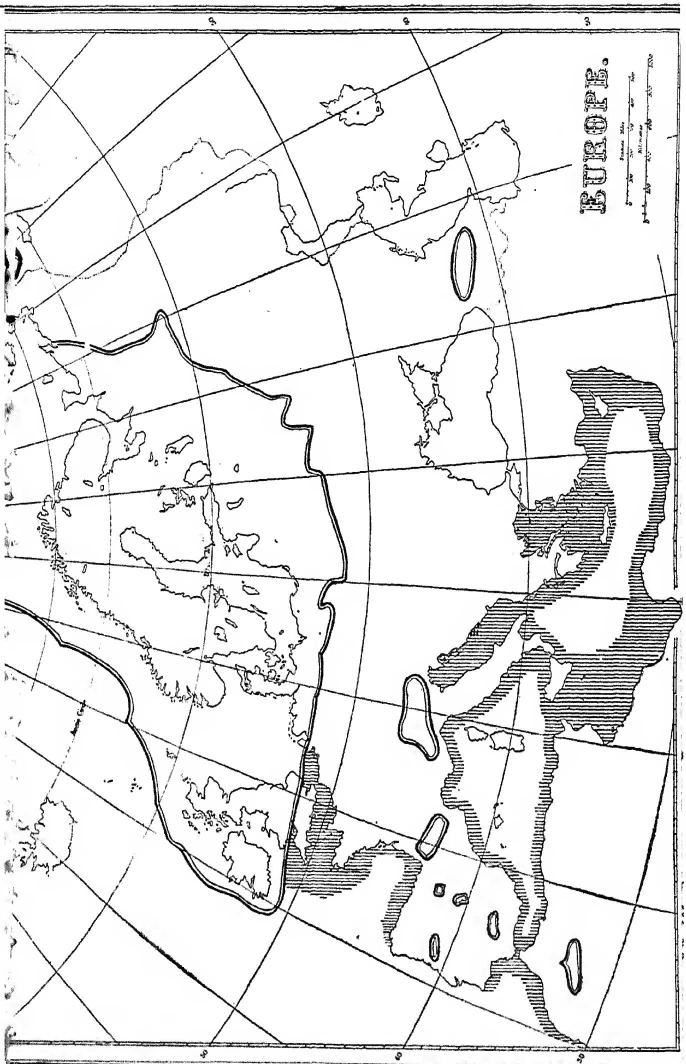
Of the Ice Age itself I gave so much evidence in the first chapter that it is hardly necessary to add more. Europe north of the Thames and Danube (and partly south of those rivers), and America north of a line drawn from St. Louis to New York, bear on their faces the marks of the Ice Age as plainly as northern France still shows the scars of the Great War. The numerous lakes—generally dammed valleys or basins scooped out of the crust—which lie in such

positions as the Swiss lakes do to-day; the boulders scattered over vast areas far from the rocks from which they came; the rounded and scratched rocks; the thousands of miles of ancient moraines or beds of glacial rubbish—all these things have been familiar for decades, and meet the eye of the student of geology almost wherever he goes. I have myself seen them—superficially, as a rule, in the course of travel—over an area of hundreds of thousands of square miles, from Germany to Chicago.[1]

Again, one must keep one's mind clear as to what is disputed and what is settled. There is now no geologist in the world who would not think it ludicrous to question the occurrence of the last Ice Age. One would as soon think of questioning the historical existence of the Carthaginians. But when it was, how long it lasted, what caused it, and whether there were inter-glacial periods, are points on which opinions differ.

In regard to the causes there is little difference of opinion, as we have seen previously. The general feeling now is that the Ice Age was due to the formation of chains of mountains. Since, in point of fact, it occurred when the chief mountain ranges of to-day reached their height, there is not much room for differ-

[1] For America the United States Geological Survey has issued (1916) a beautiful volume on the evidences of glaciation. But every recent manual of geology devotes much space to the last Ice Age.



THE LAST ICE AGE. LARGEST EXTENT OF THE ICE-SHEET AND EXTENSION OF THE DRY LAND

ence of opinion. The constancy with which we find these two phenomena associated in the story of our planet, and the ease with which we can explain the connection, dispense us from further discussion. We saw that the great mountains of Europe, Asia, and America began to rise during the Chalk Period. We can trace that some of them continued to rise, at intervals, during the warm periods which followed the Chalk; and we can show that these elevations brought, locally, a drier and colder climate. It was one of these rises, in America, that caused the Colorado River to flow more steeply and cut its famous canyons. But the main rise was at the close of this last warm Era of the earth's chronicle. The Rockies and Andes, the Pyrenees and Alps and Carpathians, the Atlas and Himalaya ranges, then reached their height. The Ice Age followed; and we need seek no other cause.

There is a little more difference of opinion as to whether the Ice Age meant four or five glacial periods with warm intervals between them. As far as America is concerned, the leading geologists claim that they have proved five successive extensions of the ice from the mountains, with four comparatively warm periods between. A few maintain that there were six glacial extensions; a few others that there were only three. It is a technical question that does not greatly interest the general public. We need note only that the second (Kansan) spread of the ice is regarded by the American geologists as by far the greatest; but as man

was not then in America we are not much concerned with it.

The chief authorities on the glaciation of Switzerland also claim five glacial and four inter-glacial periods, and they are generally followed. But there is, especially among recent geologists, more difference of opinion about Britain and northern Europe. Many geologists state categorically that there was only one glacial period in England. Others believe that man arrived here during an inter-glacial period. As far as the point concerns us, we will return to it later.

Assuming that there were inter-glacial periods, the explanation would be on lines which we have previously suggested. Take North America. We find the bones of whales and seals several hundred feet above the present sea level and far inland. Near Montreal such bones are found at a height of 520 feet. Clearly the land has risen a good deal since the Ice Age. This probably means that during the Ice Age the earth's crust was pressed down by the enormous weight of ice and snow which it bore in North America, and the sea encroached. The vast broken hollow which we call Hudson's Bay seems to be a permanent relic of the depression. The Baltic region and the flooded fiords of Norway appear to demand the same explanation. It is suggested that this depression of the surface by a great mass of ice may have led to a milder climate, and that, as the ice then melted, the earth may have risen again. So some

would explain the five glacial and four inter-glacial periods. Eight million square miles of permanent ice and snow—that was the greatest extension of the ice-sheet—mean a most formidable load, when we recall that a column of ice only 200 feet deep and a yard square weighs half-a-million pounds.

The differences of opinion are far more pronounced on the most interesting question of all: when the Ice Age began, and how long it lasted. The most favoured estimate in America is that the first glaciation began about 600,000 years ago, and that the last ended from 50,000 to 20,000 years ago. Professor Chamberlin, in a rather older estimate, makes the Ice Age last from 1,020,000 to 20,000 years ago. Professor Schuchert, one of the most recent writers, estimates the whole period at from 400,000 to 1,400,000 years ago; and he says that the latter figure is probably nearer the truth. The radiological estimate of the age of the earth would require an even larger figure than this. On the other hand, Scandinavian geologists claim to have fixed the end of the Ice Age in their region at 30,000 years ago, and some—who say that the place on which Stockholm is built to-day was under ice 9,000 years ago—even at 7,000 years ago.

In other words, the subject is so obscure, and the estimates are so conflicting, that we shall have to proceed with great care and reserve when we come to the question of man's contact with the Ice Age. Yet this is the most interesting of all questions in connec-

tion with the last Ice Age, and we shall see to what extent science can give us a satisfactory idea.

Here any person who wishes to follow intelligently the references to discoveries of early man which now occur so frequently in the press will find it useful to remember just one or two geological terms. The story of the earth is, as I said, divided into Eras (see p. 63). The last, and shortest, of these is called the Cenozoic Era.[1] If we take the whole story, for convenience, as a matter of a hundred million years this Era lasted about five million years. It represents the time between what we called the Cretaceous Revolution and that with which we are now concerned, the Pleistocene Revolution. The last section of this Era is known as the Pliocene Period, and the entire stretch of time since its close is called the Pleistocene Period. These are the two words which occur invariably when there is question of early human remains. The Pliocene is the Period before the Ice Age began, or the last part of the Cenozoic Era. The Pleistocene is from the beginning of the Ice Age until the dawn of history.

It is quite certain that man appeared long before the Ice Age, or in the first half of the Cenozoic Era. We have no remains whatever—not even rough stone implements—belonging to those early days, but it is none the less certain that man was on the earth. It

[1] At one time it was commonly called the Tertiary Era, as the whole of geological time was then divided into *three* main sections. The name still occurs, but it is now inappropriate.

is now beyond any question that man and the man-like apes came from a common stock, and, as we find remains of such apes in strata which belong to the middle of the Cenozoic Era (or before it), we know that our branch of the Primate family must have been in existence at the same time—a time that we may conceive, on the most moderate estimates of geological chronology, as between two and three million years ago. No doubt the ancestor of our race that then existed was only semi-human; possibly not very different from the apes of the other branches of the family. Probably its home was South Central Asia, or the lost land of which the islands of the Malay Archipelago are fragments. All the evidence up to date seems to me to point to the latter.

But, whatever the cradle of the race was, man wandered into Europe before the Ice Age began; and with this point alone we are concerned here. A year or two ago (1920) Mr. Reid Moir, one of the best experts in East Anglia, found flint implements of a fairly advanced type underneath the Boulder Clay near Ipswich. He and others stoutly maintain that the earliest implements on (or under) British soil belong to the Pliocene Period. There are the usual differences of opinion. Some would say—perhaps this is now the general opinion—that man was in Britain (which was then not yet cut off from Europe) before the Ice Age began; some would say that he reached Britain during an inter-glacial period.

The dispute must be mentioned in any account of man and the last Ice Age, but it does not affect the view which I am putting before the reader. On the one hand, it is practically certain that man entered Europe from the south-east, and it would take ages before the primitive, sluggish, ape-like wanderer reached the part which we now call England. If the man-like apes were in France at least a million years before the Ice Age, as they were, we need not hesitate to assume that man was somewhere in Europe before the end of that million years. On the other hand, it is perfectly certain and agreed that the race was spread over Europe before the great extension of the ice and snow which covered four million square miles, and this is precisely the glacial period which "made man."

With these reserves, therefore, let us picture to ourselves what happened on the lines which most of the authorities follow. Strewn fairly thickly over parts of the eastern counties of England (though not confined to these) are certain very crudely chipped flint implements which are known as Eoliths. The workmanship is so slight that some still question if they are not merely flints that have been accidentally chipped or knocked together; but they are now generally admitted. They are found also on the other side of the North Sea, and, as the North Sea was then dry land, these very primitive humans probably found it a congenial country, with plenty of food. In the

same region—East Anglia—we find also the next type of flint implement (rostro-carinate). Taken together, the two sets of implements seem to indicate a very long sojourn of primitive man in eastern Europe long before the Ice Age.

Whether the bones of the Piltdown man (or Eoanthropus) are remains of this race is a very thorny question. One badly shattered skull and bits of a second skull were found at Piltdown, and the best authorities estimate that the brain was quite large. On the other hand, the lower jaw was so brutal that some at first regarded it as belonging, not to the man, but to a chimpanzee. A somewhat similar, though slightly higher and later, jaw was found at Heidelberg in Germany—unfortunately without any trace of the upper part of the skull. All agree that these are the earliest remains of man in Europe, but the claim that the brain was large is very puzzling. Let us leave it open. It is difficult to believe that such a jaw was associated with a "modern" type of brain; and it is significant that only the lowest kind of stone culture is found in strata of that age (at least 400,000 years ago). I do not think that the last word of science has yet been said on the subject of Piltdown man.

We reach firm ground, knowledge in which all the scientific men of Europe are agreed, when we glance at an early European race which is known as the Neanderthal race, or—we may roughly say—man of the Old Stone Age. Of this race we have about thirty

skulls, whole or partial, and several skeletons. They are all consistent, and the type is well known, as I have elsewhere described it. This was man at the beginning of the Ice Age: more than a million years old, yet lower in mental endowment and culture than the Australian black is to-day. This was the race that passed through the ordeal of the Ice Age.

I have dealt somewhat fully with this period in the first chapter of my *A B C of Evolution*, and here I will be content to make certain important points clearer. The first is the question of climate. It may seem to the inexpert more or less of a conjecture when we say that the primitive European lived at first in a warm climate, with abundant food, and passed into the stress and scarcity of an Ice Age. But the evidence is positive. Both the animal and plant remains tell us the climate of a region at any particular time. We saw that before man came into Europe the climate was so warm that palms grew in the latitude of London and Paris, monkeys swung from tree to tree, and the elephant and hippopotamus found the temperature suitable. We then find, as we pass to higher levels, that the palms and the monkeys retire southward, but the earlier traces of man are contemporary with the elephant, rhinoceros, and hippopotamus. Step by step we can follow this early European race, by means of the bones of its animal contemporaries, into a colder and drier climate, until at last man shivers

in caverns amidst a region of ice and snow, and the woolly elephant and reindeer replace the older types of animals.

Again we must call to mind the physical revolution which underlay the human story. Man had entered Europe when it was generally low-lying and warm. Our mountain chains had, as we saw, been arrested in their development, and had largely been worn down again. Europe was, in fact, the best continent for man to spread in. The European race was not "called" to a great destiny by some mystic vital force, nor was it endowed with some remarkable germ-properties which other races had not. These mysticisms explain nothing—they are mere verbiage—and are superfluous.

What was unique about Europe was its physical history. America was too far away; the only land-bridge to it (Alaska) was in a remote and bleak region. Asia, we can see, was becoming very mountainous and inhospitable. Africa was forbiddingly hot and unhealthy, and the narrow valley of the Nile through which we might imagine primitive man approaching it—the one gap through its northern barrier of desert—did not yet exist in those days. The black had probably entered Africa, and *become* black, from land on the north-eastern coast which exists no longer. Europe was, on the whole, the best continent; and man early spread over Germany, Italy, France, Spain, Belgium, and England. Then Europe began to rise,

as we saw, and to prepare for its children the drastic ordeal of an Ice Age.

The change is well expressed in a distinction which used to be made in the science of prehistoric man. Earlier man was called "river drift man"; later "cave man." A dozen different stages, with names that would only bewilder the reader, are distinguished to-day, but the old distinction expresses a fact of the broadest and greatest importance. Earlier man of the Old Stone Age, who left his implements in the river gravels, was an open-air man; a naked, homeless, speechless, primitive type, not particular about his food and not needing to exert himself to find it. Man of the later Old Stone Age, who lived in caverns, was a higher and far more progressive being: a maker of clothes and fire, a hunter, accustomed to decorate his weapons. Step by step he advances as the great ice sheet slowly spreads over Europe and drives him into his rock shelters and caverns.

And here is the second point of great importance. Did the oncoming of the Ice Age convert man into a social animal, and precisely on this account put him in the way of more rapid advance? I have in the earlier work summarized the evidence that man was not a social animal before the Ice Age, and that he began to lead a social life during it Recent research has made no difference in this evidence, and I will not repeat it. Everything we know tends to show that social life began round the fires which man learned to

make when the cold set in, and under the rock shelters where some protection was afforded from the biting winds. That was the real making of man. There is no reason whatever to suppose that the pace of human progress would have increased as it did if there had been no Ice Age.

To what I have said elsewhere about the stimulation given by social life let me add here that the Ice Age converted man into a hunter. On the analogy of very lowly savages—lower than the Australian, as many are—we can imagine man before the Ice Age. He literally "picked up" his living—lizards, insects, dead animals, eggs, shell-fish, etc. His only weapon for ages was a stone that he held in his hand, without a handle. At the most he might throw it at an animal. To what extent could such a man be a hunter? His bones show that he was a heavy, slow-moving creature, and his weapons (of which we have millions of specimens) reached only as far as his arm reached. What animal could he hunt? The wolf, the fox, the deer, the horse, the wild ox, or dog? Every animal could outpace him. Even if we supposed that he hunted in groups, it would make little difference. An elephant or a rhinoceros would hardly remain passive while a score of Palæolithic savages tried to gash its flanks with hand-carried stones.

Arrow-heads and spear-heads begin with the Ice Age. Man had become a hunter. The drawings which he has left us show that he hunted the rein-

deer, the mammoth, the wild ox, and the wild horse. In some places great piles of horse bones accumulated. They are clearly hunting camps. Neanderthal man had become both social and a hunter. Food no longer lay about on every hand. Even in summer what was left of Europe, apart from the northern ice sheet which reached the valley of the Thames (with glaciers even on the South Downs) and the great Swiss ice sheet, was bleak enough. In winter it must have been frozen over. Vegetation was scanty. Fish and shell-fish were unobtainable half the year. It was necessary to store food against hungry days. "Big game" hunting was imposed upon man; and we can broadly realize the stimulation it would give to his intelligence. This and social life explain the rapid advance of man in the cave-period; and it was the Ice Age which necessitated both.

The next step was agriculture. A hunting community must wander a good deal. It exhausts a region, and must move to another. When man learned, or noticed, the meaning of the seed—when he could sow food at his own door and garner it for the winter—he could have settled villages, the germs of towns and of civilization. We should not expect this discovery in glacial Europe. But the larger part of the inhabitants had been driven out of Europe, and they were pinned in a relatively small region between the African desert and the frozen North: some in Morocco and Algeria, most of them at the eastern end

of the Mediterranean (which was then dry land). This concentration led to social life and (as the conditions of life were here less exacting) to even greater progress. The primitive barbarian of Europe became an artist. The primitive migrant from Europe became, in a more genial world, a farmer.

The end of the Ice Age would, as we saw, be at a different date in different regions. The south would first enjoy the new conditions and be stimulated by them. But even in its end the Ice Age shaped the course of human history. The swollen waters of the Nile cut the valley of Egypt through the desert, and gave it its covering of wonderful soil. The swollen rivers from nearer Asia filled up the arm of the sea which is now Mesopotamia. For the primitive farmer here were two rich territories. About the same time the basin of the Mediterranean was flooded. As the ice of Europe melted, the level of the Atlantic rose higher. Hundreds of thousands of millions of tons of ice and snow were transferred to the ocean. Probably the ocean then burst through the gap at Gibraltar. At all events, we know, on positive grounds, that a large part of the land between Italy, Greece, Asia Minor, Palestine, and Africa was then flooded.

I refer to my previous book for the working out of these consequences. Briefly, this central idea connects together all the threads of the evolution of civilization in different regions. It explains why south-eastern Europe was the great stage of civilization, why

there was a "Mediterranean race," why the white race became the chief representative and developer of civilization. The discoveries of the last twenty years have illumined the whole story. However perplexing may be the earlier part of man's history, the later part, the advance to civilization, can no longer be regarded as a mystery.

CHAPTER VIII

THE NEW ERA OF EVOLUTION

WE have now completed, in outline, the story of the earth's revolutions, and it is plain that we are guilty of no exaggeration in giving that name to the Ice Ages. Geological time was divided into three Eras long before the earlier Ice Ages were suspected, or the last Ice Ages fully known. There were great breaks of some kind in the geological chronicle. The continuity of nature's processes was somehow broken. Now we understand these natural divisions. Between each of the older geological Eras was a revolution, physical and biological; and the obscure primordial Era, or Eras, that we have added to the older ones also witnessed an Ice Age.

That these were physical revolutions is now clear; and I trust I have shown, in the small space at my disposal, that they were also biological revolutions. What effect upon life the first two Ice Ages had we do not know. But the chronicle is very complete as regards the third, fourth, and fifth revolutions. It is enough to recall that the third brought upon the scene the mammal and the bird; the fourth made the earth

suitable for the mammals and birds, and secured their triumph; the fifth, in stimulating the evolution of man towards civilization, rendered the greatest service of all. The story of life becomes intelligible. Great as are the mysteries that still lurk within the organism, it is merely foolish to confine one's attention to these obscurities and say that we face the general problem of the evolution of life with no more knowledge than men had fifty years ago. One half the problem has been wonderfully illumined.

I need not repeat that this triumph has entirely confirmed and expanded the main principle which Darwin put before the world fifty years ago. But it will be useful to conclude with some consideration of the relation of these matters to social problems and methods.

And in the first place it is necessary to make entirely clear that all this study of evolution in the past has no direct lessons at all for present and future evolution. One looks back with a smile on much of the sociological literature of the late nineteenth century, and even of the early decades of the twentieth. There was a distinguished man of science in Austria, Professor Virchow, who rejoiced the reactionaries all his life by refusing to countenance Darwinism (in which he privately believed); and his reason was that Darwinian ideas led to Socialism. But there were even more numerous writers who assailed Socialism on the express ground that it was inconsistent with

Darwinism. It was one of those wordy warfares which are so frequent in social literature, where argument and rhetoric are apt to take the place of facts. Both sides were wrong. Darwinism is a description of the past; social idealism of the present and the future. The laws and processes of the past are not the laws and processes of the future.

Broadly speaking, what the whole of this slow advance of life during tens or hundreds of millions of years—this long struggle for food and (above a certain level) for mates, this slow oscillation of the crust of the earth which changes and destroys the life-conditions of myriads, this periodic invasion of the planet by intense cold—what it all means is that life had to be *goaded* onward. The living population of the earth was like a flock of sheep that had to be turned here and there: like a pack of dogs that had to feel the lash and the rein. We may say what we like about heredity, but this is the quintessence of the evolution of life up to now. Fishes may have had—must have had—the most wonderful germinal potentialities, but they did not leave the water until physical changes in the earth's surface drove them to do so. It was the same with all the other great steps in evolution. The lash was laid on the back of the animal world. The spur of adversity sank into it.

But social idealism makes or imagines laws for a totally different material. It assumes that it is legislating for intelligent men and women. It sup-

poses that it is dealing with living beings who can *see* the goal, and can, if it is attractive enough, make their way to it without spur or lash. That never happened before in the history of life on the earth. All the earlier animal populations were blind in this respect. They went where they were driven. Man alone can frame an ideal which will draw and direct him. If you care to put it so, he is driven by the luminous thing, the vision, in his own mind; but it makes all the difference in the world, for the lash of outward circumstances is no longer needed.

Hence the appearance of man ought to start a new era in evolution. If I may use a rather bold metaphor, it should be like the opening of an era of automatism or automobilism. The old type of carriage was an inert thing; it went where it was dragged. That was the pre-human animal. The motor car does not wait to be dragged. Man is now supposed to have the motive power and the chart of the way in his own mind. He is "the master of things," not the slave of things. The old laws of progress do not apply to him.

An animal was made strong or cunning in the old era by fighting. Unless it fought, through a long series of generations, it lost its potentialities and might even lose its actual qualities, as birds on islands where there are no enemies lose the use of their wings or as fish in dark caverns lose the use of their eyes. Man does not need that external stimulus. It is

nonsense to say that he needs fighting to develop his strength, for athletic exercises devised by himself will do it just as well—and he will not leave his well-developed muscles in some stinking grave on the athletic field. It is nonsense to say that he needs competition to develop his intelligence; for he could develop it in isolation.

That is to say, in theory; and there you have the key to the whole confusion. Man is changing, but he has not yet changed. Some men are a new type of creature, looking before and after. A great many are not. Few have fully developed the new faculty. We live in the phase of transition from evolution by the lash to deliberate self-evolution; and every age of transition is confused and painful. It is said that there are 1,700 million human beings on the earth. Two-thirds, or more, of them have no idea whatever of a new power or a new era. They have lived under the lash of pastors and masters so long that the new idea of self-government, if it reaches them at all, dazes them. Even in civilization the majority hardly know what it means; and the majority of those who know, and try to realize it, are checked by the difficulty that they must act collectively, and in order to do so they must think collectively, which will take a long time.

And if the logically-minded reader asks whether this state of humanity is to last until there is a new Ice Age, the answer need not be too modest. I have

shown that there is a very curious and positive reason to suspect that the interval of time between Ice Ages is shortened by about fifty per cent. every time. Why this is so no one has yet attempted to say; but the facts are so remarkable that it looks like a "law." Now, supposing that the interval between the fourth and fifth Ice Ages was about five million years—a low estimate—and that the fifth is over, the sixth might be expected in two or three million years from to-day. If anybody thinks that the human race will have to wait so long as that for wisdom, he would, one would imagine, like Huxley, "hail the coming of some friendly comet to sweep us to destruction."

On the contrary, the new era of evolution will by that time be so far advanced that physicial revolutions will cease to control the world of life. We say that the last Ice Age is over. This may not be quite accurate. It may be that the earth will grow so much warmer that the Swiss ice, and much of the Polar ice, may disappear We are in the penumbra of the Ice Age, even if we say that it is over. Most probably in the course of some tens of thousands of years Europe will become warmer. It is wearing down. Then will come, at a time which seems to us colossally remote, yet is small on the geological scale, the sixth Ice Age. If the interval goes on decreasing by fifty per cent., the Ice Ages will at last run together, and the entire earth be glaciated. If, as seems probable, man is still on this globe when that occurs, it will make

no difference to him. His command over matter will have reached such a pitch that he will be able to live without cornfields or cows.

Much of this, no doubt, sounds like romance. But it is very sober romance. Take the last four Ice Ages, and the intervals between them as suggested on p. 63. If we take the story of the earth as a hundred million years, it is plain that we are justified in expecting the sixth Ice Age in from two to two and a-half million years; and we should fairly expect permanent glaciation in five or six million years. On that scale of time (a hundred million years for the earth's past) mathematicians say that they have very good reason to expect at least ten million further years of life on the earth. If you multiply the figures by seventeen, as the radiologists demand, the permanent glaciation would not be expected for eighty million years; but on the other hand, man's lease of life is extended to something over two hundred million years! If there is any romance in this, it is not my feeble fancy that can claim the merit. It is a direct inference from the statements of our most brilliant geologists and physicists.

And this—to return to our social theme—is precisely the spirit which the world wants: a basis of most carefully ascertained fact, and then an audacity like that of our great intellectual constructors. The revolution which will inaugurate the new era of evolution will not be physical. If there are any laws of life at

all, it will be intellectual and emotional. The heavy conservatism of the race will be shaken by as mighty an upheaval as the physical uplift which shattered the conservatism of the salamanders of the Coal Forest or the reptiles of Mesozoic Europe and America. The evolution of mind will have its revolutions—its rapid periods—as had the evolution of matter and of life.

It is clear that we have entered upon such a period. Speaking quite soberly, attending to the historical facts alone, there never was in the world before such intellectual movement as there has been during the last half or three-quarters of a century. One has only to recall the religious and political changes which have affected the minds of hundreds of millions of people. We have to pay the price of this movement. In all earlier ages movement was from one definite political or religious type to another: from monarchy to republicanism, from one religion to another known religion. The alternative existed or was clearly conceived. The difficulty of our age is that we are compelled to look beyond all the familiar types to create new ones; and for a time the situation is bound to be intellectually chaotic. Moreover, modern civilization has economic problems of a magnitude that was never dreamed of in the world before. So we necessarily have an age of controversy, of intellectual differences. The danger is that the mass of people may be tempted, from weariness, to shirk the task. The supreme requirement is that we shall keep our mental

life at the highest pitch of efficiency which the hard conditions of life permit. Our "national education" is largely a sham. We must do what we can to help each other; and even the most drastic intellectual challenge is a help, provided we can keep our tempers, maintain a high level of character, avoid conceit in our own opinions, and appreciate the causes of more conservative opinions.

This is no place to indicate what the author thinks to be the goal—speculative, political, economic, moral, or social—towards which we should agree to tend. I am dealing with general laws and dispositions. I am showing how the factors or stimuli of progress are now internal, not external. They are the mind and will of man, not Ice Ages or struggles for life.

Yet this truth must not be taken too narrowly. It does not in the least mean that material conditions lose their importance. As we have seen, one of the most acute controversies in connection with evolution is as to the respective parts of heredity and environment—of "nature" and "nurture," as is often said; and there has been a strong tendency in the last two decades to depreciate, or even deny, the importance of environment. As far as the main theme of this book is concerned, my position will be clear. Darwin was right in admitting both factors, and he was equally right in thinking that for the present the study of the action of the environment is far more profitable than the study of heredity. In spite of the able and

devoted work that has been done, the fundamental mystery of heredity remains as obscure as ever. We simply have not the least idea how it is that a microscopic germ can build up a human body; but we have a very vast and profound and interesting knowledge of the selective machinery of the environment.

Hence, as far as past evolution is concerned, environment is as important as ever. And when we say that the factors of progress now *ought* to be internal, we have not the slightest intention of lessening the importance of environment. All that is meant is that a man endowed with reason, will, and emotions ought not to wait for the stimulus of adverse circumstances, as life has done hitherto. The revolutions of the past, which were very progressive but deadly periods, inaugurated "golden ages" which were very stagnant and unprogressive. Man's mental power makes him independent of both. He needs, or should need, no stimulation of adversity to make him advance. He runs no risk, or should run no risk, from a golden age. His mind can provide the stimulating elements, without the cruelty, of the one; and it can add stimulating elements, without losing the comfort, of the other. Evolution is giving birth to wisdom. It is the function of wisdom to create a new evolution.

THE END